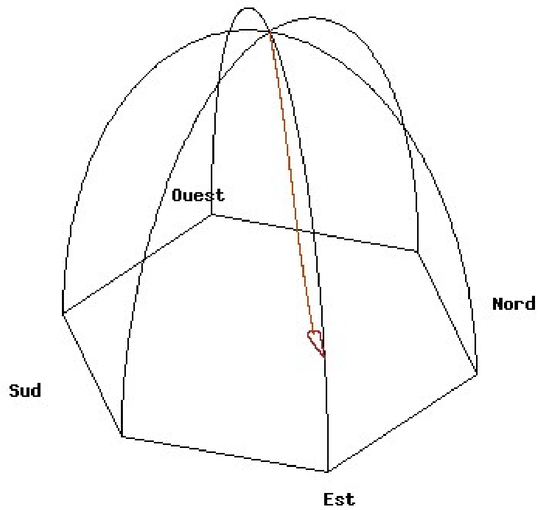
Does The Earth Really Spin? Foucault's Pendulum Vs A Helium Balloon In A Car: The Pendulum Problem



"My findings about the Foucault pendulum may very well astonish you...The surprising truth is that all Foucault pendulums are fakes. Most of them are fakes because they are forced to do what they do, rather than doing what comes naturally, and all the rest of them are fakes insofar as they are used as proof of the earth's [supposed] rotation. The only kind of Foucault pendulum which would not be a fake would be one that was free-swinging, operated properly, and either had no explanations, plaques or literature associated with it, or had such which plainly acknowledged that it cannot determine absolute rotation. I know of no such Foucault pendulum anywhere. The Foucault pendulum is a piece of scientific apparatus specifically designed and built to deceive and mislead. It is literally a "humbug" – a sham, a fake, a fraud, an artifice, a pretence, a hoax – and I believe it should be exposed as such. But the Foucault pendulum is more than a hoax. It is actually a religious propaganda tool. Foucault pendulum displays have something very serious and important to prove.' --- R.G. Elmendorf: A Critical Investigation of the Foucault Pendulum, published by P.C.S., PO Box 267 Bairdford, PA 15006, USA, Introduction. "

It's *pronounced* 'Fu-Ko'

Th explanation for the Foucault Pendulum experiment is that the Earth would spin beneath the swinging pendulum at the North and South Poles. At the Equator there would be no such effect. The mechanic for this apparent effect is supposed to be the Earth rotating on its axis beneath the fixed pivot point of the pendulum. At the North and South Poles we imagine we are motionless relative to the Earth's poles. We watch the Earth rotate on its axis and notice that the Earth is moving and the "Fixed Stars" do indeed seem fixed.

The famed Foucault Pendulum experiment was not conducted at either Pole but instead, the experiment was originally conducted in Paris, France.

There are three problems with this explanation.

1. If the pivot point for the pendulum is located anywhere other than the North or South Poles, the Earth cannot possibly rotate beneath it. The pendulum's pivot point is now no longer centered on the point about which the Earth rotates, it is in fact now possesses tangential velocity unlike what it would posses at the poles. At the Poles we are to suppose that the Earth would somehow rotate beneath the pivot point of the pendulum.. In other words the pivot point and the entire apparatus is dragged with the rotating Earth. **One can only imagine this experiment logically taking place at the poles. At any other point on the globe, the entire apparatus would be dragged with the rotating Earth. This invalidates this so called experiment. The premise of this so called experiment is illogical in the first place.**

This concept also ignores the very real 'laws' of conservation of energy and inertia or momentum. We can demonstrate these latter natural principles.

https://en.wikipedia.org/wiki/Acceleration#Tangential_and_centripetal_acceleration

http://www.softschools.com/formulas/physics/tangential_velocity_formula/25/

2. The Foucault Pendulum and other Coriolis type experiments do not seem to show what the mainstream scientific community claims they do. These experiments seem to ignore inertia. This is has to do with how a race car can drive along a curved wall. See below for more.

https://en.wikipedia.org/wiki/Inertia

http://phors.locost7.info/phors04.htm

3. Why does the pendulum have to be in motion? How is that different from it merely hanging at the pole? Again, why is Newtonian inertia forgotten? The erroneous concept is predicated on the idea that somehow the Earth can rotate beneath a suspended weight. How does the weight being in motion make a difference? Why not put a pointer on the weight and simply let it hang and watch the world turn beneath it? The whole concept is fantasy.

This article will attempt to explain these three points as clearly as possible with sources. The main concept is that these experiments are inconclusive and thus prove nothing as we'd expect no such motion to be detected if the Earth was rotating or if it was still. In either case, the result should be the same.

"The Foucault pendulum (English pronunciation: /fuː ˈkoʊ/ foo-koh; French pronunciation: [fuˈko]), or Foucault's pendulum, named after the French physicist Léon Foucault, is a simple device conceived as an experiment to demonstrate the rotation of the Earth. While it had long been known that the Earth rotates, the introduction of the Foucault pendulum in 1851 was the first simple proof of the rotation in an easy-to-see experiment. Today, Foucault pendulums are popular displays in science museums and universities"

https://en.wikipedia.org/wiki/Foucault_pendulum

https://en.wikipedia.org/wiki/Coriolis_force

see also:

https://en.wikipedia.org/wiki/Fixed_stars

https://en.wikipedia.org/wiki/Angular_velocity
https://en.wikipedia.org/wiki/Speed#Tangential_speed

Four Quotes

"Leon Foucault was a 19th century French scientist who, because he did not hold an advanced degree and in particular was not facile with advanced mathematics, was considered an amateur outsider by the scientific establishment of his time. He also edited a journal that explained science to the public, another role too often discredited by mainstream scientists.

You might think of him as an early version of the hero of the motion picture, "Good Will Hunting".

But Foucault was in no way a second rate scientist. His carefully designed experiments significantly improved estimates of the speed of light. He invented the gyroscope and adapted it for the telescope-aiming mechanisms astronomers still use. He also initiated the use of silvered telescope mirrors.

Far more important, the pendulum he built and finally set in motion on January 6, 1851 (the wire broke three days earlier) finally proved that the earth rotates. Remarkably, this long accepted belief had not been proved until then.

How does his pendulum establish this? ***Foucault, the excellent science popularizer, explained it this way. Suppose you swing a pendulum over a table and you rotate the table slowly. The pendulum will stay in line as the table turns. But if you sit on the table as it turns: the pendulum itself will appear to rotate. The pendulum, Foucault said, is "fixed in absolute space while, like the table, we and the planet rotate under it." The pendulum appears to us to turn slowly as it swings back and forth but it is really we who are rotating around the pendulum.****"*

"Foucault even came up with a simple formula that tells how long it takes the pendulum to rotate 360°. The time in hours is equal to 24 divided by the sine of the latitude where the pendulum is located. The latitude of the Buffalo Museum of Science is 42°54' North so it takes the museum pendulum about 35 1/4 hours to rotate. It turns just over 10° per hour. The original in Paris at 48°50' North took just under 32 hours. With or without math, you should be able to determine how long it would take at the North Pole.

Clearly Foucault brought to his experiment deep insight. Unlike an engineer who would employ a series of trials he supported his theory by a single experiment."

"Much of the information for this column is derived from a delightful book by Amir Aczel entitled *Pendulum: Leon Foucault and the Triumph of Science* (Simon & Schuster). I highly recommend reading it for more about this hero of science".-
- Gerry Rising

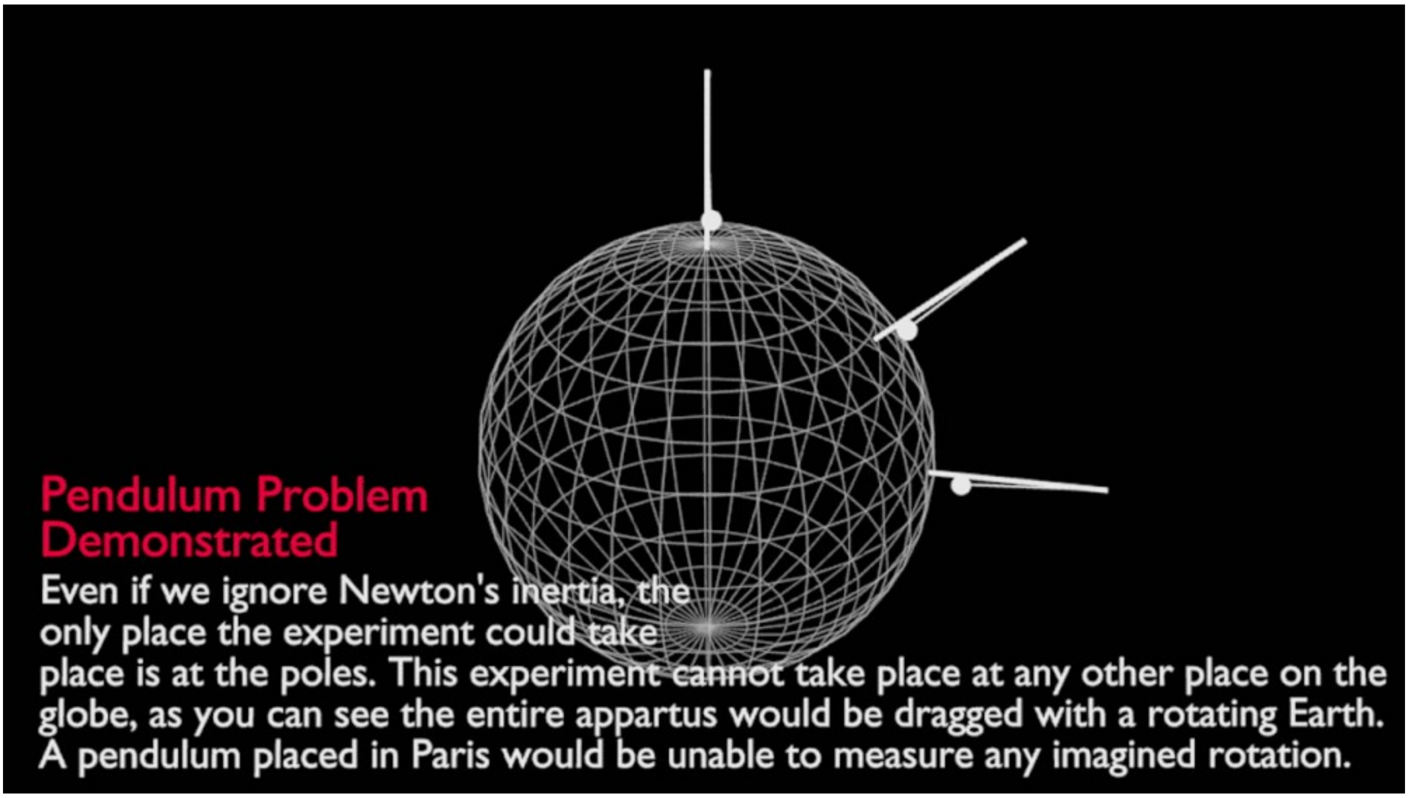
http://www.acsu.buffalo.edu/~insrisg/nature/nw04/0307Foucault.htm

"Ever since the time of Copernicus it had been taken for granted that the Earth is rotating on its axis. Nevertheless no one had actually demonstrated the fact. It seemed stationary, and no effect had been observed (other than the apparent spin of the sky) that could be attributed to the rotation. In 1851, however Jean Foucault suspended a large iron ball, about 2 feet in diameter and weighing 62 pounds, from a steel wire more than 200 feet long...The swinging pendulum would then remain in the same plane, but the earth, as it rotated, would change its orientation. If the pendulum had been at the North Pole, it would do a complete circle in 24 hours. At the latitude of Paris, the

change would have taken 51 hours and 47 minutes. Thus the spectators were actually watching the Earth rotate under the pendulum.' --- I. Asimov, Science and Discovery, Grafton Books, 1990, p.323.

'The Foucault pendulum is one of the best-known experiments in the history of science. It created a sensation in its first public showing in Paris in 1851, and has fascinated scientists and laymen ever since. ...
This article discusses the history, construction, operation, theory and meaning of the Foucault pendulum, presenting facts about it which are not generally known or understood by the millions of visitors who view these fascinating displays in science museums, schools, planetariums, observatories and other public buildings all around the world every year."
"My findings about the Foucault pendulum may very well astonish you...The surprising truth is that all Foucault pendulums are fakes. Most of them are fakes because they are forced to do what they do, rather than doing what comes naturally, and all the rest of them are fakes insofar as they are used as proof of the earth's [supposed] rotation. The only kind of Foucault pendulum which would not be a fake would be one that was free-swinging, operated properly, and either had no explanations, plaques or literature associated with it, or had such which plainly acknowledged that it cannot determine absolute rotation. I know of no such Foucault pendulum anywhere. The Foucault pendulum is a piece of scientific apparatus specifically designed and built to deceive and mislead. It is literally a "humbug" – a sham, a fake, a fraud, an artifice, a pretence, a hoax – and I believe it should be exposed as such. But the Foucault pendulum is more than a hoax. It is actually a religious propaganda tool. Foucault pendulum displays have something very serious and important to prove.' --- R.G. Elmendorf: A Critical Investigation of the Foucault Pendulum, published by P.C.S., PO Box 267 Bairdford, PA 15006, USA, Introduction. "

'For simplicity, let us consider such a pendulum swinging at one of the poles. At other latitudes it will have a more complicated motion, but the principle is the same. Since the pendulum is swinging from a universal joint, the plane of its motion will remain fixed in absolute space, while the earth rotates underneath.' ---D.W. Sciama, The Unity of the Universe, doubleday, 1959, p.112.

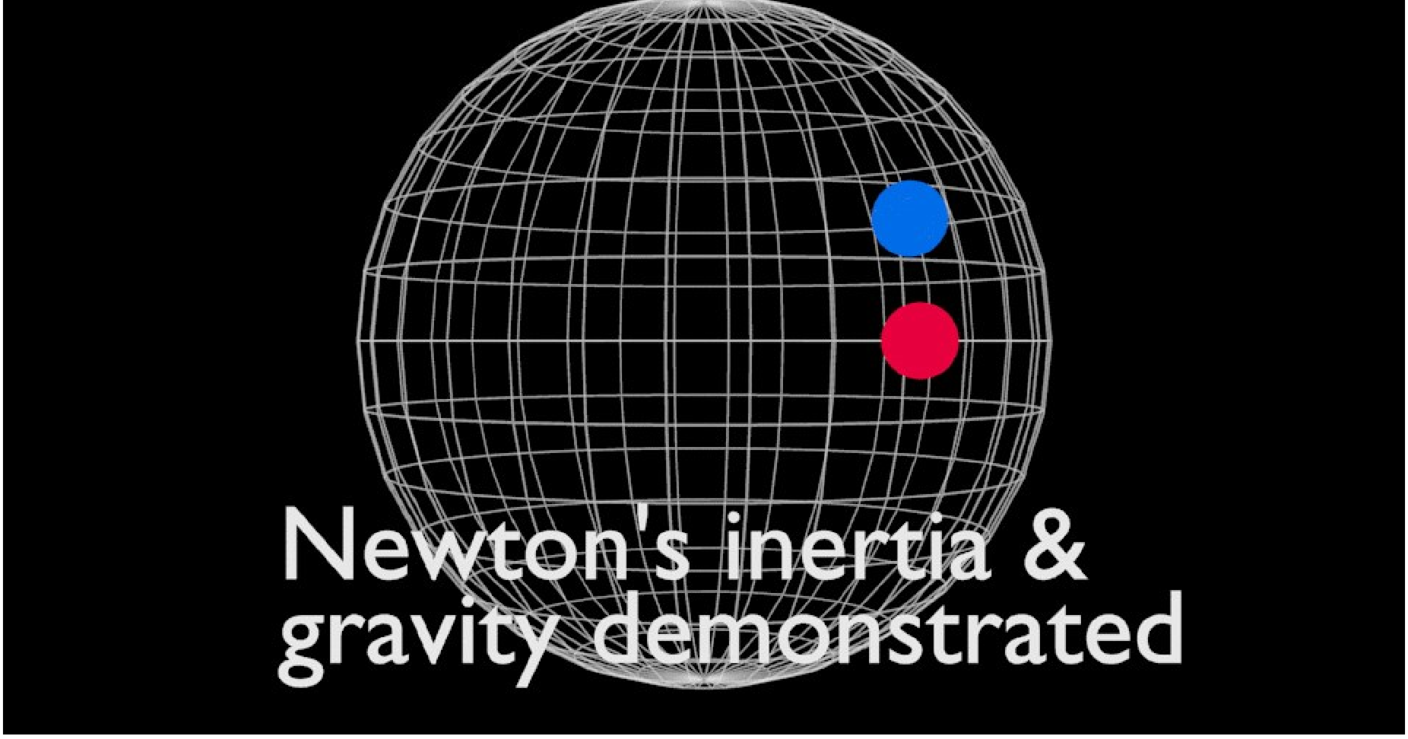


Explanation of mechanics

"At either the North Pole or South Pole, the plane of oscillation of a pendulum remains fixed relative to the distant masses of the universe while Earth rotates underneath it, taking one sidereal day to complete a rotation. So, relative to Earth, the plane of oscillation of a pendulum at the North Pole undergoes a full clockwise rotation during one day; a pendulum at the South Pole rotates counterclockwise. When a Foucault pendulum is suspended at the equator, the plane of oscillation remains fixed relative to Earth. At other latitudes, the plane of oscillation precesses relative to Earth, but slower than at the pole; the angular speed, ω (measured in clockwise degrees per sidereal day), is proportional to the sine of the latitude..." https://en.wikipedia.org/wiki/Foucault_pendulum

Shared Center of Mass, Gravity & Inertia Demo Below:

In this Newtonian Model, we must remember that the center of mass for any body caught up in the imagined 'gravity field' is supposed to be at the somewhere around center of the Earth. Gravity acts like a string of sorts and inertia provides the tangential velocity which when combined with gravity results in the rotational motion we are supposed to imagine is real. This is why pendulum and other such experiments should yield null results and cannot be regarded as proof of anything as there should be no motion detected by such means in the first place.



"In cases where one of the two objects is considerably more massive than the other (and relatively close), the barycenter will typically be located within the more massive object."

https://en.wikipedia.org/wiki/Barycenter

https://en.wikipedia.org/wiki/Center_of_mass

INERTIA FORGOTTEN

Angular Momentum Proves The Coriolis and Foucault Pendulum Experiments are Wrong and the results should be Null.

Energy is conserved. Whether we imagine ourselves on a spinning globe, whether we actually go on a merry go round or get into a car and drive in circles or up walls, the mechanical demonstrable physics are the same. A tighter turn requires more energy or the perpendicular velocity (the translational velocity) slows. The tight a turn you want to make the more energy you need otherwise your apparent translational velocity slows. Think about how a disk spins. The whole thing spins as one. The apparent per pendular or translational (tangential velocity) motion will be greater on the perimeter and will be reduced as it becomes zero at the center of the disk where the motion is purely rotational. If you walk from the perimeter of a merry go round to the center you would be demonstrating this principle.

In Newtonian mechanics we have gravity acting as a string pulling bodies towards the Earth's center of mass. If we walk to the equator we have a translational velocity of some 1000 mph. If we walk to one of the poles we have no translational velocity and are rotating. This works the same for the merry go round and for objects attached to strings.

So we should expect no Coriolis effect nor should we expect and sort of Foucault Pendulum type experiment to work, the expected result is null no matter the model of the Cosmos. Inertia and gravity make the result the same as if the Earth were not moving. The fact that this is ignored by the mainstream scientific community and contradicts the foundation of the mainstreams own theories, is telling. This is propaganda and not science.

If I shoot a projectile from the equator to the North Pole, it would possess an apparent 1000 mph velocity and would be fired towards a bullseye that was rotating. As the projectile moves away from the equator, its angle relative to gravity's pull changes and when this happens, energy is naturally conserved and the apparent translational velocity would be appropriately modified. As the turn becomes tighter, the apparent translational velocity decreases. We'd expect no Coriolis effect as a result. As the projectile approaches the North Pole, its gravity vector is now 90 degrees from where it had started. This is equivalent to you walking from the center of a spinning platform to the perimeter and back again. Friction and gravity and your constant velocity of motion are equivalent to gravity, friction and the constant velocity of the projectile. The same physical rules apply. We can demonstrate with this every experiment that the Coriolis effect and the Foucault Pendulum type experiments ignore the Newtonian concept of inertia and gravity. This contradicts one of the very foundational tenets of modern science.

An object making a tighter turn needs more energy to maintain its tangential velocity. This also applies to projectiles fired on an imagined rotating gravity possessing

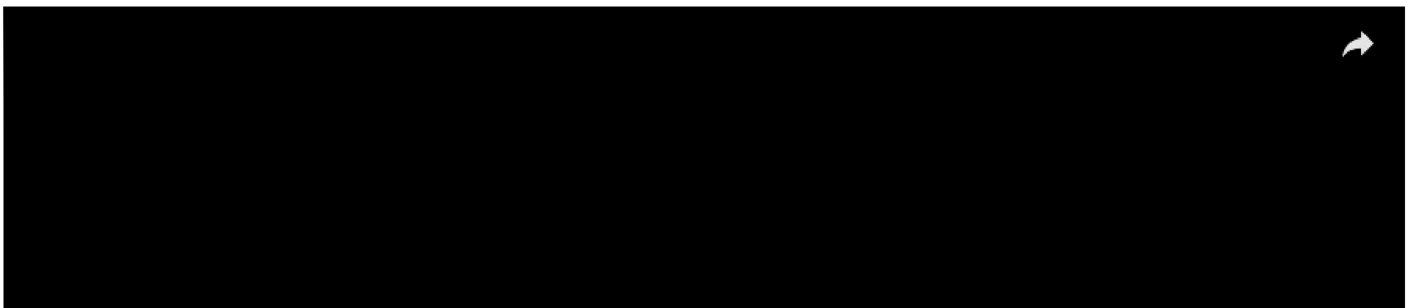
globe. No Coriolis effect nor any Foucault Pendulum type experiments should be expected to work under either a helio or geo-centric model,

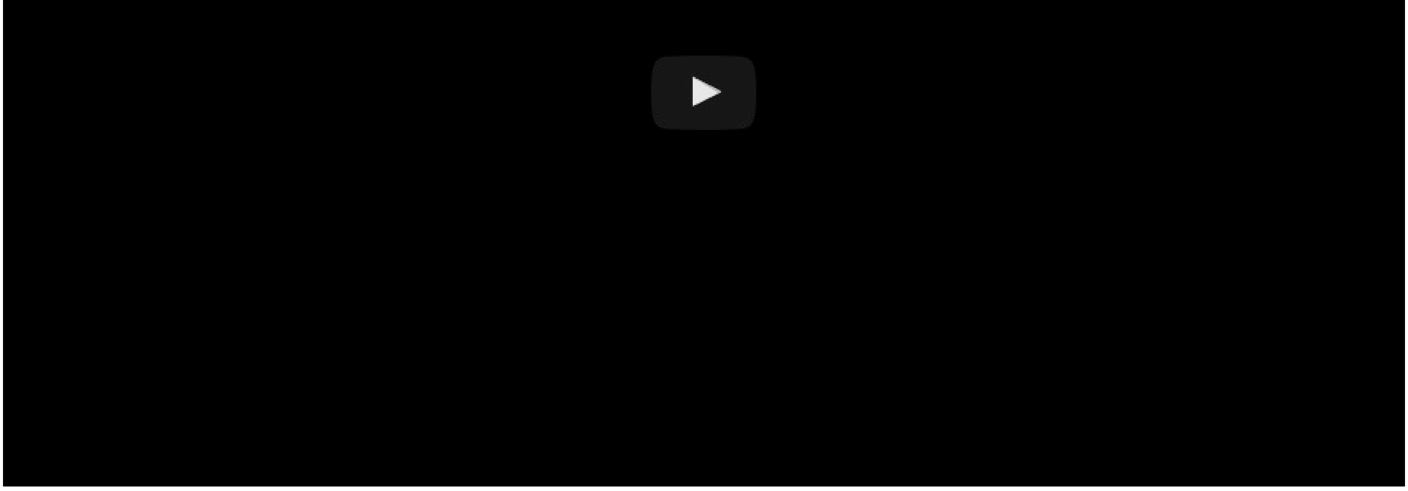
Hello Sun. Hell Oh! Halo. Hell and hall both mean the same thing as cell- to hide or conceal.
For more check out the article index.

Anyone can go fast straight: The challenge is turning. It takes more than ten thousand pounds of force to get a racecar around Turn 3 at Texas Motor Speedway at 180 mph. All that force comes from four tiny patches of rubber--the only thing keeping the car on the track and out of the wall.

"In physics, angular momentum (rarely, moment of momentum or rotational momentum) is the rotational analog of linear momentum. It is an important quantity in physics because it is a conserved quantity – the angular momentum of a system remains constant unless acted on by an external torque."

https://en.wikipedia.org/wiki/Angular_momentum
http://www.wright.edu/~guy.vandegrift/openstaxphysics/chaps/06%20Uniform%20circular%20motion%20gravity.pdf
https://en.wikipedia.org/wiki/Circular_motion
http://www.montville.net/cms/lib3/NJ01001247/Centricity/Domain/962/Chapter%209%20Uniform%20Circular%20Motion%20Principles_of_Physics.pdf





Gravitron. Please Note How The Person At The Center Simply Spins. Energy is conserved. This shows why Foucault Pendulum type experiments cannot logically show any supposed motion of the Earth. Newton's model is supposed to be based on this very idea.

A pendulum would move in opposite direction to the balloon. A pendulum or balloon could be used to measure the Earth's supposed rotation. Try it. All you will find is that the experiment yields a Null result and that you cannot prove the Earth spins on its axis.

A pendulum would not show the Earth rotating beneath it, but would show you if you were accelerating. Circular motion is an acceleration too. The supposed compounded motions of the modern Heliocentric model would mean the Earth would also have an acceleration based on its orbit as well as its supposed rotation. No balloon nor pendulum has even shown us such motion.

A Helium Balloon in an accelerating car shows there is a problem with Foucault Pendulum type experiments.

Does the very real atmosphere of the Earth act in any way like we should expect were it rotating on an imagined axis?

Gases obey these natural and demonstrable principles of motion.

Ignoring winds and air currents, have you ever seen a helium ballon do anything but rise straight up into the sky?

The helium balloon never acts as if it were on a rotating sphere.

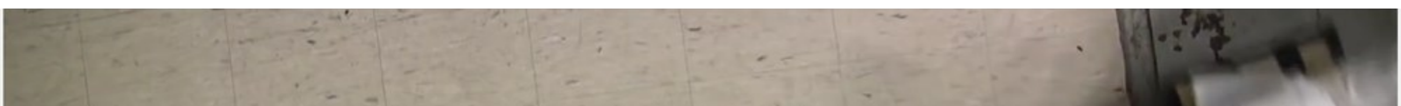
There is no logical reason to think we are in motion when we are not.

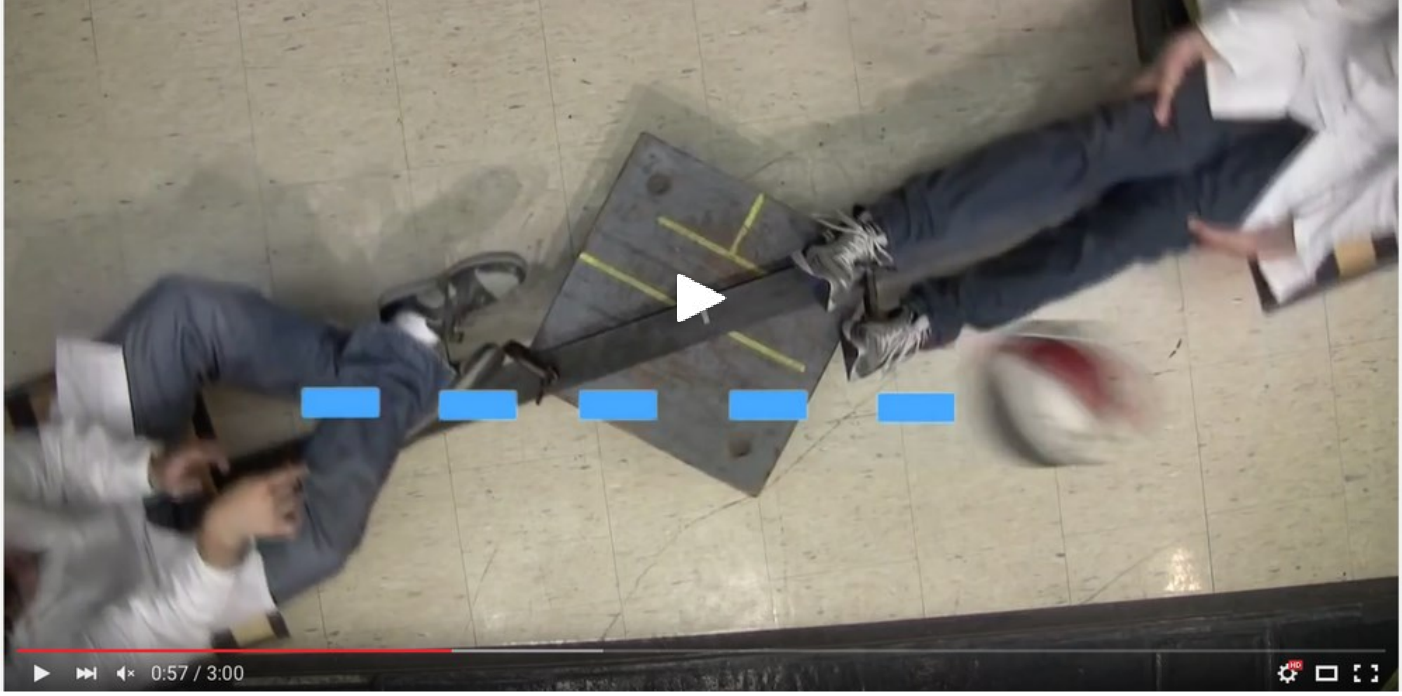
The Earth Does Not Move.

Our senses tell us this all the time. All empirical observation, logic, common sense and real experiment also prove this. Modern science is propaganda or religion. It is predicated on mathematics as the foundation and this is a mistake as math is a tool with very real human limits. Nature does not make mistakes, we do.

Baffling Balloon Behavior

Physics experiment demonstrating helium balloon inertia. Edited by Tessa Ricci Filmed by Austin Jaspers





MIT Coriolis effect demo

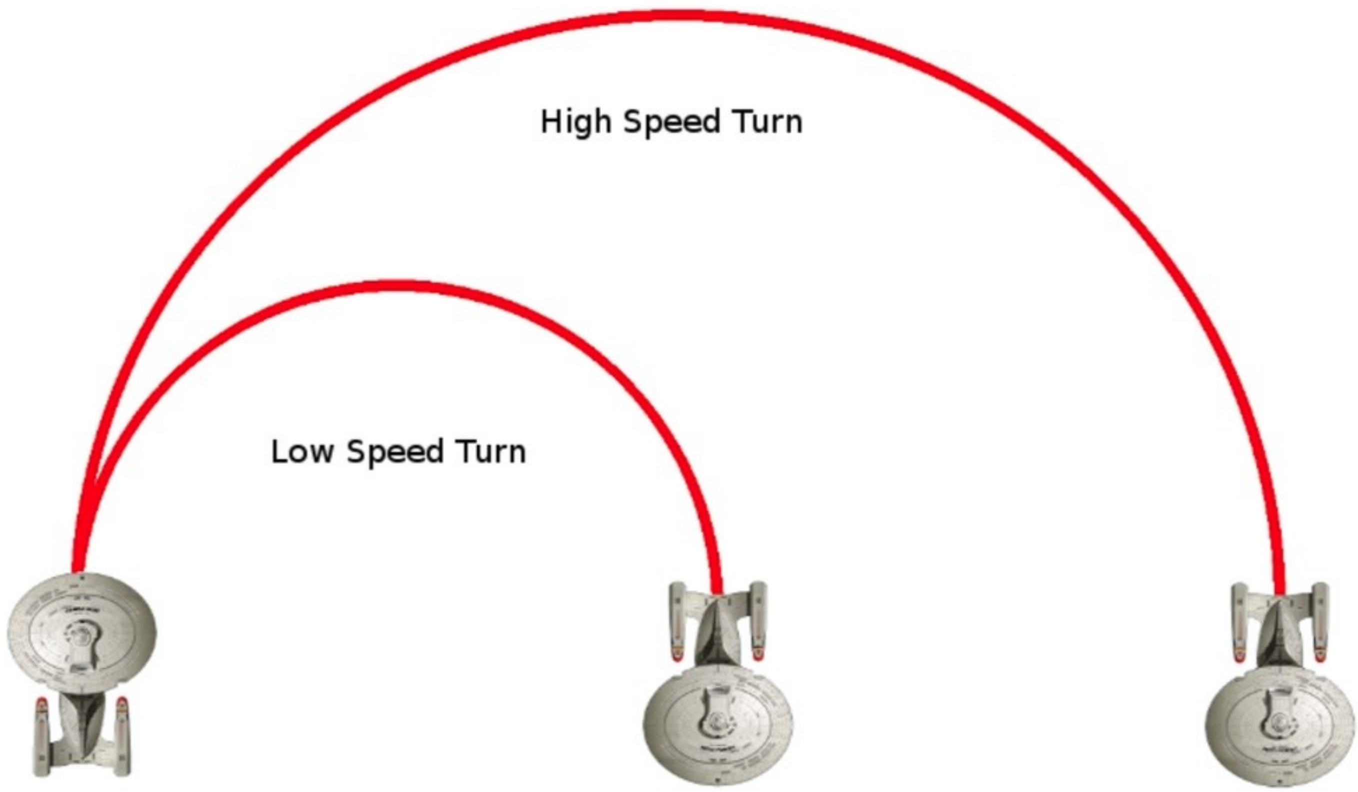
Why do storms spin in different directions depending on their location-and why do they spin in the first place? Play the Cloud Lab: http://www.pbs.org/wgbh/nova/labs/lab/cloud/ Find discussion questions for this video and other resources in the Cloud Lab collection on PBS LearningMedia: http://www.pbslearningmedia.org/resource/nvcl.sci.earth.coriolis/the-coriolis-effect/

Gravity is Considered To Be The Centripetal Force

Proving that a = v^2/r More free lessons at: http://www.khanacademy.org/video?v=XjCEumlJBno

THE CONSERVATION OF ENERGY MEANS TIGHTER TURNS NEED MORE ENERGY TO MAINTAIN THE SAME TANGENTIAL VELOCITY.

If the Ship was traveling at 7000 MPH while making the wider turn, the ship would end up traveling at a slower speed if it tried to make a tighter turn. The ship would have to increase the amount of power it was using to maintain its apparent tangential velocity. In other words the system needs more energy.



"Race tracks are rarely circles, but as a first approximation, we can consider each turn to be part of a circle and model the turning of the racecar using uniform circular motion. Uniform circular motion basically means that the object is moving in a circle at constant speed.

If I tie a string to a tennis ball and swing it at constant speed in a circle of radius r over my head, the only reason the ball goes in a circle is because the string is constantly pulling it toward the center of a the circle. The string forces the ball to turn.

Just like the tennis ball, a turning car needs a force to make it turn. If you want the car to turn left, you have to exert a force to the left. At each point in the turning circle, the force that makes the car turn is perpendicular to the direction the car is moving, which makes the force always toward the center of the circle. This center-pointing force is called the centripetal force, and it depends on the mass of the car, the speed of the car and the turn radius of the track."

$$Centripetal\ Force = \frac{(mass\ of\ car)\times(speed\ of\ car)\times(speed\ of\ car)}{(turn\ radius)}$$

"This equation tells you:

- The heavier the car, the more turning force it takes
    - Because mass only appears one, if you double the mass of the car, you need twice as much turning force
- The higher the speed, the more turning force it takes
    - The speed is squared — if you double your speed, you need four times as much turning force.
- The larger the turn radius, the less turning force it take.
    - The turn radius is in the denominator, so it acts oppositely to the mass and the speed."

"Let's look at some numbers: The minimum weight of a Gen-6 car is 3300 lbs for a driver of 180-lb, so I'm using a total weight of 3480 lbs (and dividing by 32.2 ft/s2 to get the mass). Let's look first at a wide sweeping track like Talladega, with a turn radius of 1100 ft and a speed of 180 mph throughout the turn. According to the formula, that car needs 6848 lbs of turning force.
Let's do the same calculation for Richmond, where the turn radius is only 365 ft. Whoa — you'd need 20,636 lbs to turn at 180 mph. Why? The turn radius at Richmond is about 1/3 the turn radius at Talladega, so you need about three times more turning force. This is why you slow down coming off the exit ramp on a cloverleaf. 70 mph is reasonable on the expressway, but when you're turning and especially if the turn is tight, then you need to slow down. This is also why cars don't take the corners at Richmond at 180 mph.
Let's run the numbers at a more reasonable speed for Richmond, like 100 mph. Then you get about 6,370 mph. But if you want to go 1oo mph around the corners at Bristol, you need 9,606 lbs of turning force because Bristol has even tighter turns than Richmond. "

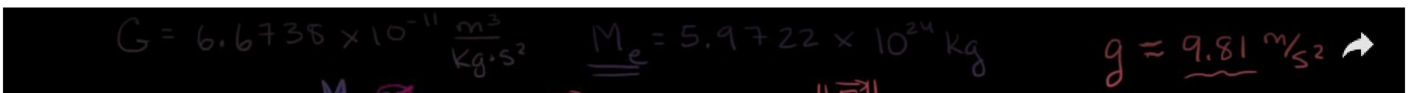
http://www.buildingspeed.org/blog/2013/04/why-turning-is-hard/

$a = rw^2 = vw$

Where a is centripetal acceleration (which is equal to the "G" we experience), r is radius, v is velocity and w is angular velocity [rad/s].

https://en.wikipedia.org/wiki/Centripetal_force

La Gravitation universelle est régie par des lois simples. Newton en a eu l'idée à partir de la chute d'une pomme et d'une expérience de pensée. (Extrait du film " Newton's Dark Secrets " Nova © 2003.)



What is the acceleration due to gravity at the space station More free lessons at: http://www.khanacademy.org/video?v=R5CRZONOHCU

"A Foucault Pendulum at the South Pole was determined to have a period of 24 hours, ± 50 minutes. The acceleration due to gravity, g, was determined to be 9.85 ms-2 ± .03 ms-2. The rotation of the Earth was in a clockwise direction if looking down from above the South Pole."

VS

"Solar time is measured by the apparent diurnal motion of the Sun, and local noon in apparent solar time is the moment when the Sun is exactly due south or north (depending on the observer's latitude and the season). A mean solar day (what we normally measure as a "day") is the average time between local solar noons ("average" since this varies slightly over the year).

The Earth makes one rotation around its axis in a sidereal day; during that time it moves a short distance (about 1°) along its orbit around the Sun. So after a sidereal day has passed, the Earth still needs to rotate slightly more before the Sun reaches local noon according to solar time. A mean solar day is, therefore, nearly 4 minutes longer than a sidereal day.

The stars are so far away that the Earth's movement along its orbit makes nearly no difference to their apparent direction (see, however, parallax), and so they return to their highest point in a sidereal day.

Another way to see this difference is to notice that, relative to the stars, the Sun appears to move around the Earth once per year. Therefore, there is one fewer solar day per year than there are sidereal days. This makes a sidereal day approximately 365.24⁄366.24 times the length of the 24-hour solar day, giving approximately **23 hours, 56 minutes, 4.1 seconds (86,164.1 seconds**)."

https://en.wikipedia.org/wiki/Sidereal_time

Problems with the Pendulum at The South Pole

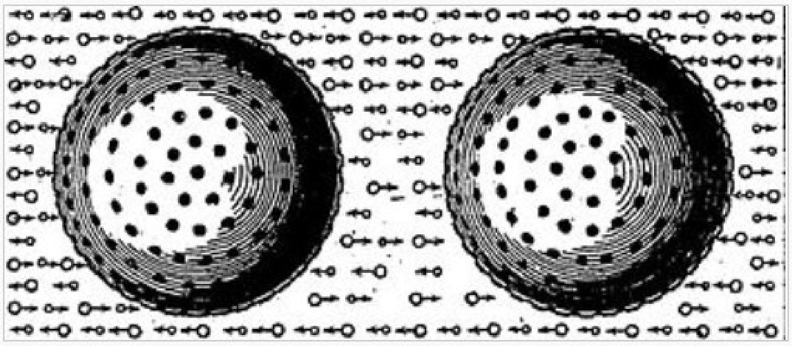
"It was difficult to make the pendulum swing in a plane instead of an ellipse. After several attempts with various techniques of holding the bob and dropping it we always got some kind of ellipse instead of a plane. This adds to our error because it is more difficult to locate and mark the pendulum arc's apex. A way to do it is to suspended the bob by tying it off with a piece of string and letting it settle, then burn through the string. The bob would then drop without any outside force and swing in a plane. Since it is against the Antarctica Treaty to have any open flames at the South Pole we could not do this. After much practice Mike Town got very adept at dropping the bob so that it arced in a plane."

"Our second attempt showed the earth rotating in the proper direction but at an angular velocity twice what is expected (i.e., 12 hour days instead of 24). We suspected some kind of government conspiracy but decided to make a further modification and try it again. Our last attempt showed that the earth spins on its axis once every 24 hours, as expected. (We were somewhat disappointed that we did not uncover a government cover-up)."

"Standing on the bottom of the world the Earth spins backward relative to the direction it spins in the Northern Hemisphere (however, water still spins down the drain in the same random direction). Our first attempt with the pendulum showed the Earth spinning backward from what was expected. We didn't notice this at first because we're all from the Northern Hemisphere and are accustomed to the earth spinning in an anticlockwise direction. We then realized that from our frame of reference the earth should be spinning clockwise so we had to modify the pendulum. At an altitude of 11,000+ feet we think a bit more slowly."

http://www.southpolestation.com/trivia/00s/southpolefoucault.html

IF ANYTHING THE PENDULUM MIGHT BE RESPONDING TO SOME KIND OF GAS PRESSURE: SEE LE SAGE GRAVITY, link below.



P9: Le Sage's own illustration of his ultramundane corpuscles

https://en.wikipedia.org/wiki/Le_Sage%27s_theory_of_gravitation

HA! LO
The Joke's In The Name "Heliocentric"

&

The Joke's Been On Us.

Heliocentric Can Also Mean

The "Hidden Center".

center (n.) Look up center at Dictionary.com
late 14c., "middle point of a circle; point round which something revolves," from Old French centre (14c.), from Latin centrum "center," originally fixed point of the two points of a drafting compass, from Greek kentron "sharp point, goad, sting of a wasp," from kentein "stitch," from PIE root *kent- "to prick" (cognates: Breton kentr "a spur," Welsh cethr "nail," Old High German hantag "sharp, pointed").

Figuratively from 1680s. Meaning "the middle of anything" attested from 1590s. Spelling with -re popularized in Britain by Johnson's dictionary (following Bailey's), though -er is older and was used by Shakespeare, Milton, and Pope. Center of gravity is recorded from 1650s. Center of attention is from 1868.
center (v.) Look up center at Dictionary.com
1590s, "to concentrate at a center," from center (n.). Related: Centered; centering. Meaning "to rest as at a center" is from 1620s. Sports sense of "to hit toward the center" is from 1890. To be centered on is from 1713. In combinations, -centered is attested by 1958.

helio- Look up helio- at Dictionary.com
word-forming element meaning "sun," from Greek helio-, comb. form of helios "sun" (see sol).

Sol (n.) Look up Sol at Dictionary.com
"the sun personified," mid-15c. (also in Old English), from Latin sol "the sun, sunlight," from PIE *s(e)wol-, variant of root *saewel- "the sun" (cognates: Sanskrit suryah, Avestan hvar "sun, light, heavens;" Greek helios; Lithuanian saule; Old Church Slavonic slunice; Gothic sauil, Old English sol "sun," swegl "sky, heavens, the sun;" Welsh haul, Old Cornish heuul, Breton heol "sun;" Old Irish suil "eye").

The PIE element -*el- in the root originally was a suffix and had an alternative form -*en-, yielding *s(u)wen-, source of English sun (n.). French soleil (10c.) is from Vulgar Latin *soliculus, diminutive of sol; in Vulgar Latin diminutives had the full meaning of their principal words.

sun (n.) Look up sun at Dictionary.com
Old English sunne "sun," from Proto-Germanic *sunnon (cognates: Old Norse, Old Saxon, Old High German sunna, Middle Dutch sonne, Dutch zon, German Sonne, Gothic sunno "the sun"), from PIE *s(u)wen- (cognates: Avestan xueng "sun," Old Irish fur-sunnud "lighting up"), alternative form of root *saewel- "to shine; sun" (see Sol).

Old English sunne was feminine (as generally in Germanic), and the fem. pronoun was used in English until 16c.; since then masc. has prevailed. The empire on which the sun never sets (1630) originally was the Spanish, later the British. To have one's place in the sun (1680s) is from Pascal's "Pensées"; the German imperial foreign policy sense (1897) is from a speech by von Bülow.
sun (v.) Look up sun at Dictionary.com
1510s, "to set something in the sun," from sun (n.). Intransitive meaning "expose oneself to the sun" is recorded from c. 1600. Sun-bathing is attested from c. 1600.
http://www.etymonline.com/index.php?term=sun&allowed_in_frame=0

geo-

word-forming element meaning "earth, the Earth," ultimately from Greek *geo-*, comb. form of Attic and Ionic *ge* "the earth, land, a land or country" (see Gaia).

Gaia (n.)

Earth as a goddess, from Greek *Gaia*, spouse of Uranus, mother of the Titans, personification of *gaia* "earth" (as opposed to heaven), "land" (as opposed to sea), "a land, country, soil;" it is a collateral form of *ge* (Dorian *ga*) "earth," which is of unknown origin and perhaps from a pre-Indo-European language of Greece. The Roman equivalent goddess of the earth was *Tellus* (see tellurian), sometimes used in English poetically or rhetorically for "Earth personified" or "the Earth as a planet."

http://www.etymonline.com/index.php?term=Gaia&allowed_in_frame=0

with the precise plane of the pendulum's movement. To be certain that the pendulum was not disturbed at the outset, it was started in motion by burning a cord that held it perfectly still and to one side. As the hours passed, the plane of the pendulum was seen to rotate. This appeared to be quite satisfactory proof that the earth rotates with respect to absolute space.

A Foucault pendulum at the equator will not rotate at all, since the plane of its motion always contains the celestial poles (Fig. 9-9A). At either of the poles, the pendulum's plane of motion will rotate once every 23 hours and 56 minutes, keeping its original orientation with respect to the background stars (B). At intermediate latitudes, the plane of motion rotates more slowly than at the poles, depending on the distance from the equator (C). To the classical physicist of Newton's time, and up till Einstein's general theory of relativity became widely known, this effect could be ascribed to only one thing: The plane of the Foucault pendulum rotates because of the effects of absolute space.

From this concept, Newton germinated the idea of absolute time as well. According to Newton, "true" time flowed smoothly, unaffected by anything external. This was indeed a bold assumption. While it is intuitively pleasing, it is based on essentially no observed facts. Relativistic physics proves that absolute time, as well as absolute space, are illusory.

In the generations following the acceptance of

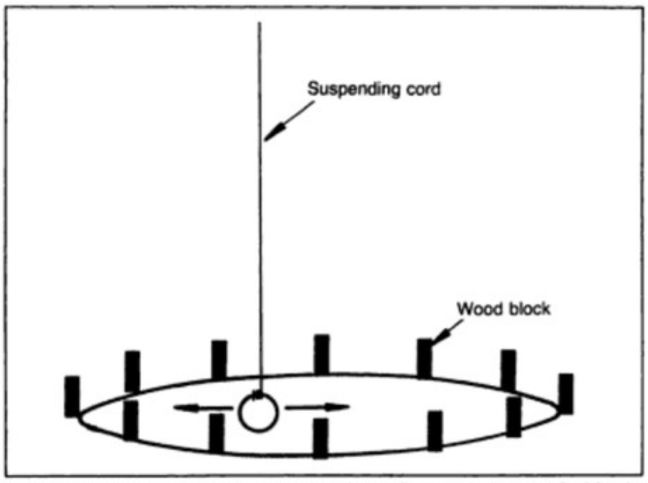


Fig. 9-8. The Foucault pendulum experiment. The cord must be very long, and there must be no air currents to disturb the swing of the weight. As the plane of the motion rotates, the weight will knock over all of the wooden blocks after a length of time, except at the equator.

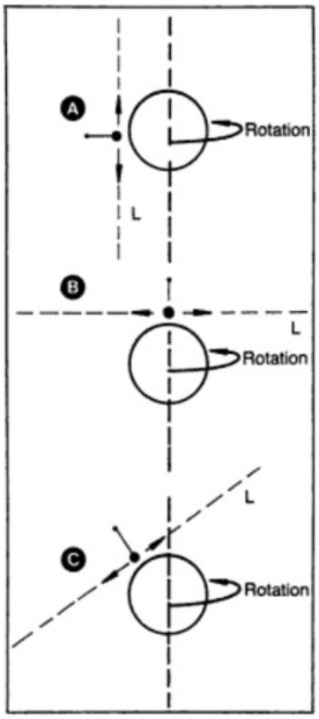


Fig. 9-9. At A, a Foucault pendulum at the equator does not rotate because its plane of motion lies in line with the celestial poles. At B, a Foucault pendulum at the pole turns "under" the earth; at C, a Foucault pendulum at intermediate latitudes rotates more slowly than at the pole. The celestial axis of the earth is shown by the heavy broken line. This experiment was believed to prove that absolute space existed, until Einstein showed that such a notion was false.

Newton's laws of gravitation and motion, many observations were made by astronomers as methods of measurement became more and more refined. Would Newton's theories accurately predict the celestial motions of all objects? Or would some exception be found? By that time, inquisitiveness was no longer the mark of the heretic; science became more research-oriented as man strove in greater unison to find the truths of the universe. Newton's laws seemed to accurately predict observed phenomena within the limits of measurement accuracy, with one nagging exception. But, one contradiction is as good as a thousand in the realm of logic.

The perihelion of Mercury changes position by 43 seconds of arc per century. Newton's laws could not explain this. The astronomer Leverrier, in 1845, carefully observed the precession of the orbit of Mercury, and it was definitely real. There it was: the one indisputable flaw in an otherwise apparently perfect model of the universe. Attempts were made to explain this strange observation, but a satisfactorily model did not come into being until Einstein's time.

THE ADVENT OF MODERN COSMOLOGY

The beginnings of relativity theory, which set the minds of astronomers in a new direction, were conceived when scientists began to seriously investigate the nature of radiant energy. The speed of light was discovered to be finite. Newton has proposed that light was like a barrage of particles. Particle-like properties of light were indeed found, but some experimenters noticed that it behaved like an oscillatory, or wave-like, effect. It was natural to ask why light traveled through interstellar space; evidently there was no air in those far reaches, since orbiting bodies do not slow down from friction. How could any effect be propagated through a perfect vacuum? Newton's particle theory explained the problem tolerably well, but observed diffration effects indicated that light had oscillatory properties. What was doing the oscillating?

This question led to the postulate that some sort of propagation medium, called the "lumeniferous ether," existed for electromagnetic waves, just

Understanding Einstein's Theories of Relativity: Man's New Perspective on ...By Stan Gibilisco

that it must be set in motion with great care and protected from external disturbances, which, it is said, develop irregularities in its motion. In a recent article in a scientific journal on "A Laboratory Method of Demonstrating the Earth's Rotation," it is stated that the Foucault pendulum method is inapplicable in many laboratories because there is no con-

venient place to hang a sufficiently long and heavy pendulum.

We shall probably never be quite certain of the exact conditions under which Foucault's celebrated experiment was performed. Our sources of information, in addition to the very brief records of the French Academy of Sciences,[1] are the papers published by Mme. Foucault,[2] ten years after Foucault's death, and the contributions of Lissajous[3] and Flammarion,[4] published still later.

Most of the important information concerning the pendulum of the Pantheon in its final form, is found in one of the papers in Mme. Foucault's "Recuile," entitled "Explications sur l'experience relative au mouvement de la terre." This paper was without date and had not been published by Foucault himself, though he is said to have published a similar paper in le Journal des Debats in March, 1851.

That the work was rushed through in great haste is indicated by Flammarion's statement that it was undertaken n January, 1851, and Mme. Foucault's statement that it was presented to the French Academy of Sciences, February 3 of the same year.

The records are not in perfect agreement concerning the dimensions of the pendulum in its final form, but the evidence is abundant that it consisted of a mass of 28 kilograms, suspended by a steel wire about 67 meters long, strained somewhat beyond its elastic limit. The fact that the wire was greatly strained is important later on.

A few years ago I set up a 60-foot Foucault pendulum consisting of an iron ball weighing about 8 kilograms, suspended by a No. 18 brass wire, from a tolerably good though by no means perfect double knife-edge support. The ball was provided with a spike at the bottom to enable the observer to determine its position, as it moved back and forth over a chart provided with a circular scale calibrated in degrees.

The performances of this pendulum were not very satisfactory and I attributed its partial failure to the presence of air currents in the shaft. However, after trying the pendulum a number of times, I found that its eccentric behavior was repeated over and over again in much the same

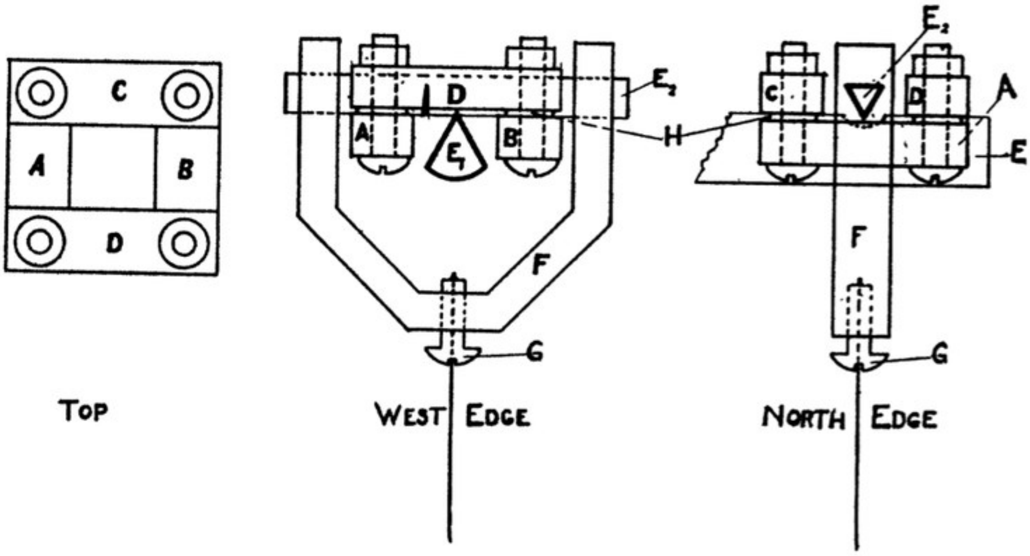
way. I could not convince myself that such *regular* "irregularities" were accidental, and I was quite sure they were not due to the uncertain shifting of air currents.

For the purpose of making a closer study of the Foucault pendulum and its behavior, I moved this pendulum to the lecture room, suspending the 8 kilogram ball from a more carefully constructed double knife-edge support attached to one of the ceiling beams over the lecture table.

The pendulum was now a little more than 2½ meters long. It was started swinging by tying the ball back and burning the thread, in the usual way. It was allowed to swing through an arc of about 10°.

A few preliminary experiments gave me reason to believe that none of the seemingly irregular movements of the pendulum were in any way chance or accidental, but that they could all be produced and reproduced under perfectly definite conditions.

The double knife-edge support used is shown in detail in Figs. 1 and 2.



Figs. 1 and 2.

E_1 and E_2 are the knife-edges, $ABCD$, the rocker, consisting of hardened and polished steel plates bolted together at the corners, and F, a brass hanger, carrying the wire in a machine screw, G, which facilitates substituting one wire for another.

The upper knife-edge could be raised or lowered by varying the vertical distance between the plates of which the rocker was made. This might be done by means of micrometer screws, but in these experiments it was done by inserting thin metal plates between the upper and lower halves of the rocker, as at H, in Figs. 1 and 2.

With this support the behavior was that of a Blackburn pendulum with slightly different periods in two directions at right angles to each other. Since the elliptical motion of a Blackburn pendulum depends upon the ratio of these two periods, it ought to be possible to adjust

the distance between the planes of the double knife-edge support in such a way as to get any desired amount of eccentricity, or to eliminate it altogether.

In one of the preliminary experiments with the double knife-edge support adjusted at random, the pendulum started on its elliptical path, rotating clockwise as viewed from above; and I noticed that as the minor axis of the ellipse increased in length, the shift of the plane of vibration of the pendulum, as marked by the position of the major axis of the ellipse, increased at an abnormal rate. After verifying this fact by repeated observations, I undertook to investigate the relation of the length of the minor axis of the ellipse, to the position of the major axis.

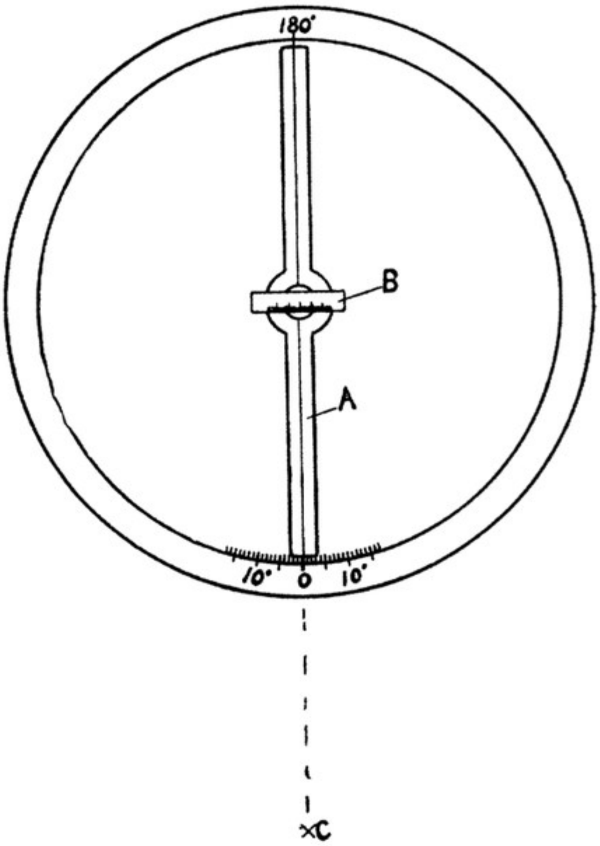


Fig. 3.

I placed a movable index, A, Fig. 3, upon the circular scale over which the pendulum was swinging and mounted a scale of millimeters, B, at right angles to it at the center of the circle. The index consisted of a light wooden bar with a screw running through it at the center, and with a fine black line running lengthwise along the bar from zero to 180° on the scale.

With a pendulum provided with a sharp spike travelling close to the black line on the movable index, and with a suitable lens placed as at

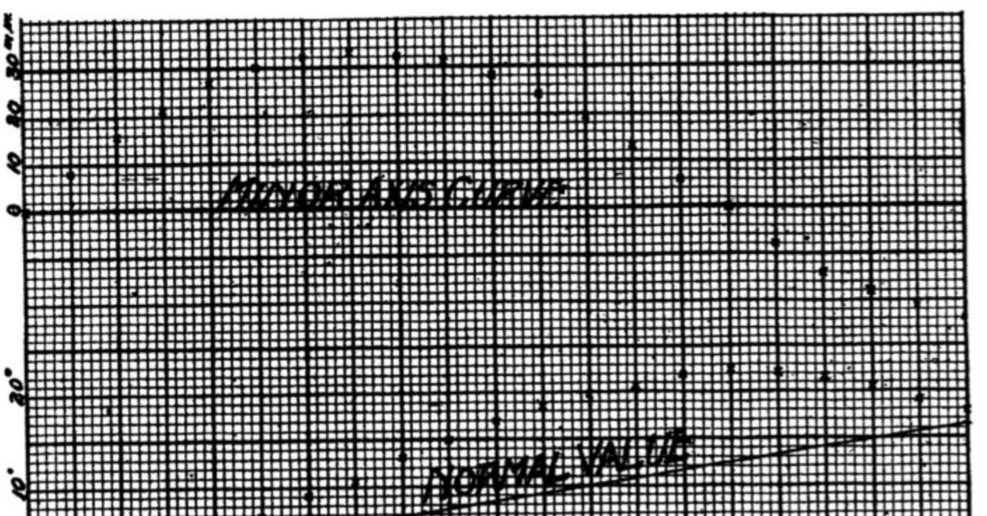


Fig. 4.

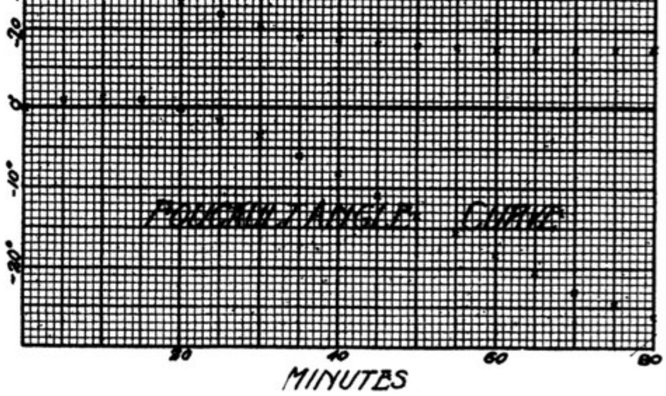


Fig. 5.

observations which followed. That is, it did not complete a half cycle and reverse its direction of rotation as it did in the preceding series.

The curves for this series are shown in Fig. 5.

Our first glance at these curves failed to reveal the fact that they had anything in common with those in Fig. 4, but further inspection shows that they are alike in the fact that they both show that counterclockwise rotation of the pendulum tends to reverse the direction in which its plane of vibration is shifting.

However, I had in Fig. 4 a part of a cycle in which the rotation of the pendulum was mostly clockwise, and in Fig. 5 a part of a cycle in which the rotation was entirely counterclockwise.

reverse as it falls, because the net effect plotted is the minor axis effect plus or minus the real Foucault effect.

At this point I thought my troubles were over, for it now seemed that in order to get a normal Foucault angle, it would only be necessary to adjust the double knife-edge support for equal lengths of the pendulum in both directions. Then there would be no elliptical motion, and consequently no shifting of the plane of vibration except that due to the rotation of the earth on its axis,—the normal Foucault angle.

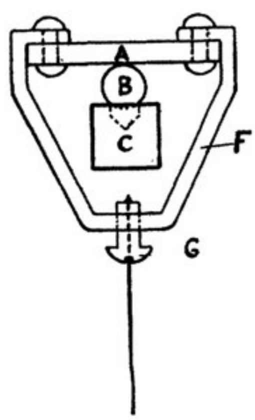
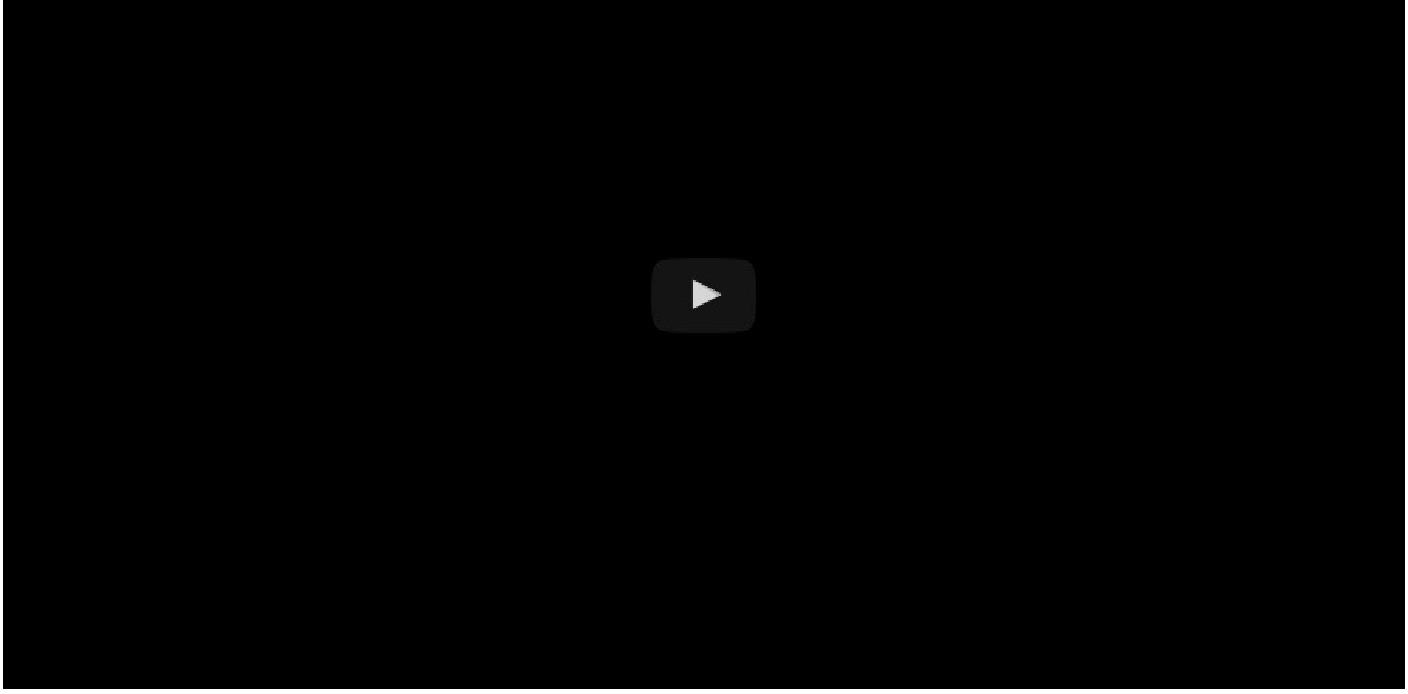


Fig. 7.

I expected to arrive with very little difficulty at an adjustment which would eliminate the elliptical motion, but all my efforts in this direction were futile. In sheer desperation I abandoned the double knife-edge and designed the following ball and plane support:



Foucault's Pendulum is a clever way of demonstrating the Earth's rotation - but it won't work at the equator! More physics at http://www.sixtysymbols.com/

motion to unevenness in the wire, although numerous measurements failed to reveal any great lack of roundness and there was nothing to indicate imperfections of any kind. I could not see that it would have made any difference if the wire had not been round or even if it had been more flexible in one direction than in the other, for with the ball and plane support, the pendulum was perfectly free to swing in any direction and the wire was not expected to bend at all. It was expected to swing with perfect freedom from the point of contact between the ball and plane. The correctness of this assumption was demonstrated later by substituting a flat steel ribbon for a round wire.

Nevertheless the pendulum behaved as if it had two periods. Furthermore it *always started* rotating clockwise, *never* counterclockwise. This fact remained a puzzle until another wire was substituted for the wire which I had been using. The two wires were cut from the same piece, and were certainly as nearly alike as two wires could well be, and yet the pendulum now *invariably* started rotating *counterclockwise—never clockwise.*

I immediately hit upon the curl in the wire as the cause of the elliptical motion. The wire was brass spring wire, and had been lying in a coil about 25 centimeters in diameter, until the "set" in it was very pronounced.

After starting the pendulum a number of times with the new wire and getting always the same results, *counterclockwise* motion at the start, I rotated the *wire* 180 degrees on its own axis, without disturbing either

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In a series of experiments which followed, for the purpose of studying the effects of the curl in the wire, I decided not to use the ball and plane support on account of its tendency to rotate at the upper surface of the ball.

The ball and plane support has no advantage over a perfectly constructed double knife-edge support. It even has some disadvantages; but it at least proved valuable in detecting some of the defects in the wire, which perhaps would not have been detected otherwise.

In order to eliminate the effects due to the rotation of the hanger in the ball and plane support, and also the possibility of two periods, resulting from lack of perfect adjustment of the double knife-edge support, and yet to retain a rotary adjustment of the wire, I designed the following torsion head plate support.

grandes pour permettre d'observer la déviation que est alors de 60 à 70 degrés." Or, "La montre à la main, ou voit que, à Paris, la déviation est du un degré en cinq minutes."

Such statements can not be thought of as representing precise measurements. They are good enough to leave no doubt in regard to the general proposition that the earth rotates on its axis, but they are not by any means exact. If success depends upon great length and great mass, Foucault's results ought to have been very exact. The fact that they were not, indicates that there was something else to be reckoned with. I have already referred to the fact that his wire was strained beyond its elastic limit, and I have no doubt this condition of the wire contributed to his success quite as much as its great length. Of course the great mass of the ball was responsible for the strain upon the wire, but if the wire had been *annealed*, the great mass would not have been necessary.

To use a pendulum of very great mass in order to prevent atmospheric disturbances is also quite unnecessary. Air currents, if forcible enough,

do disturb the pendulum slightly, but such disturbances never "develop large irregularities" in the motion of the pendulum, in spite of certain ingenious theories intended to explain how they do it. In fact they never *develop* any irregularities at all. They always die out gradually, and at the same rate as the decrement in the principal motion of the pendulum along the major axis of the ellipse, when the amplitude has been reduced to the same value. Would you dare present any other view of the case to your students if you were discussing the second law of motion?

How unimportant slight atmospheric disturbances are, may be indicated by the fact that I have succeeded perfectly with a 1 kilogram pendulum in an ordinary lecture room with all the doors and windows open (2 doors and 7 windows) and a good breeze flowing through the room.

The majestic oscillations of the Pendulum of the Pantheon, as Flammarion fittingly describes them, must have produced a profound impression upon those who had the good fortune to observe them; but it is not possible to repeat the experiment in every lecture room on such a magnificent scale. To reduce the experiment to convenient lecture room dimensions, ought to greatly extend its field of usefulness.

KNOX COLLEGE,
GALESBURG, ILL.,
October, 1918.

Sylvester's discretion prevented him from naming George B. Airy, the astronomer royal, and the Reverend Baden Powell, Savilian Professor of Geometry at Oxford University, as the mistaken scientists. In private correspondence, Airy had repeatedly dismissed the Foucault pendulum experiment as a "fraud." He regarded the latitude-dependent formula for the period of the apparent precession of the pendulum as a "mathematical curiosity having no application whatever to the *soi-disant* experiment." Attending no demonstrations, Airy based his conclusion on oral accounts of the experiment. Concurring with Airy, Powell accepted the theory but held that as a "practical question" the experiment was "doubtless open to every kind of doubt." After learning of successful demonstrations by British scientists, Airy conducted his own experiments. Although it was possible to conduct the experiment properly, he concluded that the "difficulty of starting a free pendulum, so as to make it vibrate at first in a plane, is extremely great."[8]

Although Airy and Powell kept their opinions private, popular journals learned of their rejection of the experiment. Linking Airy's and Powell's doubts to recent unsuccessful popular demonstrations of the experiment, these journals questioned the validity of the Foucault pendulum. The *London Literary Gazette* recommended caution to those who would attempt the experiment because "persons unqualified by previous habits of research and accurate investigation" had failed. The *Literary Gazette* knew of several exhibitions "in which, to the horror of the spectators, the earth has been shown to turn the wrong way." The *Illustrated London News* expressed similar reservations, observing that the "experiment is now giving rise to much controversy, and it is hard to conceive that there is not some fallacy lurking at the bottom of it." Parodying this controversy, *Punch* reported

that a correspondent named Swiggins had observed the earth's rotation in a manner that should satisfy those "sceptical and obstinate" persons who doubted that it was visible. After six cups of brandy, Swiggins did not need a pendulum to convince him that the earth was spinning; he had only to look at the ceiling.[9]

on the Foucault pendulum at a public demonstration of the experiment at the Royal Institution. Listing the repetitions conducted by scientists in Britain and Europe, he noted that the "accordance of many of the results at different places within fair limits of error" confirmed the validity of the experiment. Powell cautioned, nevertheless, that the "sources of error are numerous and not easy to be effectually guarded against." He reasoned that "these causes of error" affected "many of the public repetitions" whose results did not conform to theory. Powell also noted that Airy had confirmed the experiment. On 9 May, Airy had presented his results to the Royal Astronomical Society. Two months later, Airy observed in an address before the British Association for the Advancement of Science that the Foucault pendulum had "excited very great attention both in France and England" by "visibly proving, if proof were necessary," the earth's rotation. Although now "certain" that "Foucault's theory is correct," Airy warned that "careful adjustments" were necessary. "For want of these the experiment has sometimes failed."[10]

Unconvinced by these explanations and aware of scientific hoaxes perpetrated by charlatans, several newspaper editors rejected the Foucault pendulum as a fraud. After "patient study," the editors of the *Providence Post* rejected the experiment as "nonsense." Citing

[34] *Boston Morning Commonwealth*, 5 June 1851, p 1; *Providence Journal*, 21 May 1851, p. 2; *Trenton State Gazette*, 27 May 1851, p. 2; *Scioto Gazette*, 2 June 1851, p. 2; *Friends' Weekly Intelligencer*, 1851, *8*:75; and *National Intelligencer*, 30 May 1851, p. 2.

[35] *Boston Evening Transcript*, 6 June 1851, p. 2; *Sci. Amer.*, 1851, *6*:312; *American Railroad Journal*, 1851, *24*:355; *Appletons' Mech. Mag. Eng. J.* 1851, *1*:406–407; *Providence Journal*, 24 May 1851, p. 2, 28 May 1851, p. 2; *National Intelligencer*, 30 May 1851, p. 2; *Cincinnati Commercial*, 8 June 1851, p. 1; Norton to Loomis, 24 June 1851, Elias Loomis Papers; and Loomis, "Notice of the New Experiment" (cit. n. 26), p. 509.

[36] *Providence Journal*, 21 May 1851, p. 2, 28 May 1851, p. 2, 12 July 1851, p. 2, 28 Aug. 1851, p. 2, 29 Aug. 1851, p. 2, 6 Sept. 1851, pp. 1–2.

no sources, they asserted that the pendulum followed the magnetic meridian and "is undoubtedly just about as much a demonstration of the rotation of the earth, as may be found in the binnacle of any vessel in our harbor." The *Charleston Mercury* took no notice of the Foucault pendulum except to reprint an unidentified Scottish experimenter's assertion that the experiment did not work because the pendulum followed the earth's magnetic meridian. The *New York Herald*, the *Savannah Daily News*, and the *Providence Journal* reprinted *Punch*'s method of affirming the earth's rotation with liberal doses of brandy.[37]

The *Louisville Democrat* borrowed *Punch*'s joke to ridicule its rival, the *Louisville Journal*, which endorsed the Foucault pendulum. The two newspapers incorporated the experiment into partisan political dispute. In a series of fourteen editorials, the *Democrat* lampooned its Whiggish opponent for having been duped by the "pendulum hoax," and the *Journal* defended itself by adducing names of scientists who had repeated the experiment. Observing that the earth was "no Locofoco editor to be ashamed of her movements," the *Journal* noted that the earth proudly demonstrated its movement to the Foucault pendulum. The paper called upon John L. Smith, who had performed a recent demonstration

to settle the matter. Unconvinced by the explanation made by Smith or by doctors of medicine, theology, or chemistry, the *Democrat* would only accept the verdict of a true authority such as Pierre Simon Laplace. Adducing the support of Joseph J. Sylvester and William C. Bond, the *Journal* observed that "if we are not to take the opinion of doctors in medicine, of lawyers in law, and of philosophers in matters of philosophy," then every man would be "his own doctor, lawyer, and philosopher"—with disastrous results.[38]

In late August, the annual meeting of the AAAS in Albany revived the pendulum mania. In addition to local newspapers, the *National Intelligencer* and the *New-York Tribune* sent reporters to the meeting. The Foucault pendulum had "half turned the heads of philosophers for some months past," Bird's Eye of the *National Intelligencer* observed, and it continued to do so. For two days discussion of the Foucault pendulum excited "general interest," with demonstrators presenting results and answering questions from the audience. Members of the AAAS—ranging from Eben Horsford, who had performed the famous Bunker Hill demonstration, to William Kitchell, who rejected the experiment after his repetitions consistently deteriorated into ellipticity—took a leading role in popularization of the Foucault pendulum, performing almost half of the identified public demonstrations. Despite this varied participation, the AAAS took notice only of the results of demonstrations conducted by a few practitioners and researchers—George R. Perkins, Lieutenant Edward B. Hunt of the United States Engineers, William Norton, and Horsford.[43]

Norton and Horsford alone had noteworthy results. After twenty-three trials of the pendulum they vibrated at the Providence railroad depot, Norton and Alexis Caswell had discovered that the apparent precession of the pendulum took longer than theory postulated, but they resisted speculation as to the cause of this discrepancy. They believed that the expected results could be obtained only by experiments in a closed room with a heavy weight and a long wire. Waiting several weeks until the number of spectators at the Bunker Hill Monument diminished before making detailed observations, Horsford discovered that the heat of the sun expanded the stones of the monument, which moved the pendulum's point of suspension. On sunny days the monument leaned northward about three-fourths of an inch. To compensate, Horsford changed the point of suspension once or twice a day according to the intensity of the sun. Joseph Henry found the discovery of the monument's movement a "very interesting result." The *New-York Observer* agreed, noting that "it is wonderful to think that the Bunker Hill Monument is bending like a bow backward and

forward every day by the influence of the sun!" Although Horsford had informed newspapers of this finding a month earlier, it remained newsworthy.[44]

Like the AAAS, Chester Lyman ignored demonstrations performed by many practitioners and cultivators. In two articles for the *American Journal of Science*, Lyman surveyed American demonstrations of the Foucault pendulum, identifying sources of error and comparing them to European demonstrations. He limited his review to his demonstration at New Haven, Bond and Horsford's at Bunker Hill, Loomis's at New York University, and Caswell and Norton's at Providence. Unaware of any demonstrations in which the oscillation of the pendulum did not gradually deteriorate from a rectilinear motion to an elliptical one, Lyman identified this tendency as the greatest obstacle to conducting the experiment successfully. Although an able experimenter could keep the ellipticity small, Lyman doubted that it would be possible to "conduct the experiment so skillfully as entirely to avoid these sources of error." Even with "theoretically *perfect*" conditions and apparatus, Lyman reasoned, the pendulum would travel in a slightly elliptical motion because of the

http://www.ewu.edu/Documents/CSBSSW/History/Conlin/Conlin_Reception_Foucault_Pendulum.pdf

https://en.wikipedia.org/wiki/Earth%27s_rotation

https://en.wikipedia.org/wiki/Earth%27s_orbit

"Under acceleration, a helium-filled balloon inside of a car will jump forward in the direction of acceleration. I have been searching for the reason why with no definitive results. This is the dilemma: An acquaintance of mine, who has a degree from Johns Hopkins is attempting to argue for some magical force that drives the balloon forward, also that it has something to do with gravity."

"In answering this question, I'm assuming you accept that a helium balloon rises in the presence of Earth's gravity. Because helium has a smaller density than air, the buoyant force of air will push it toward the sky against gravity. If you want a more detailed explanation of that, please submit another question."

Answered by:

Alan Chodos, PhD
Associate Executive Officer
American Physical Society

http://www.physicscentral.com/experiment/askaphysicist/physics-answer.cfm?uid=20130711030801

Resolving the equation of motion of motion in components, and ignoring z motion,

$$\begin{aligned}\ddot{x} + k^2 x &= -2(\vec{\omega} \times \vec{v})_x = +2\,\omega\,\dot{y}\,\sin\lambda \\ \ddot{y} + k^2 y &= -2(\vec{\omega} \times \vec{v})_y = -\,2\,\omega\,\dot{x}\,\sin\lambda\end{aligned}$$

We have already solved this kind of equations previously. Write $\xi = x + iy$. Then,

$$\ddot{\xi} + 2i\omega\,\dot{\xi}\,\sin\lambda + k^2\,\xi = 0 \qquad (15.40)$$

This equation is very similar to the equation of a damped harmonic oscillator except the damping constant is imaginary. The solution is,

$$\xi(t) = e^{-i\omega t\sin\lambda}\left[A\,e^{i\,t\,\sqrt{k^2+\omega^2\sin^2\lambda}} + B\,e^{-i\,t\,\sqrt{k^2+\omega^2\sin^2\lambda}}\right] \qquad (15.41)$$

But $k^2 >> \omega^2$. (There are many oscillations of the pendulum in 24 hours). Then the part in square bracket represents usual oscillations of the pendulum. Prefactor represents effect of Corioli's force. Thus the plane of oscillation of the Foucault pendulum rotates with the period,

$$\tau = \frac{2\pi}{\omega\,\sin\lambda} \qquad (15.42)$$

Observe, there is an infinite period of rotation of the plane of oscillation on equator ($\lambda = 0$) i.e., the plane of oscillation does not rotate. On poles, λ is $\pm 90^0$ and $\tau = 2\pi/\omega$, which is same as period of rotation of Earth. At $\lambda = 30^0$, τ is 48 hrs.

Clearly, Foucault pendulum is an experimental proof that the Earth is a rotating system relative to fixed frame of reference.

Classical Mechanics

Introduction: the 1905 debate

One hundred years ago the German journal *Annalen der Physik*, the same 1905 volume in which Albert Einstein published his first five ground breaking articles, provided a forum for a debate between three physicists, A. Denizot, M.P. Rudzki and L. Tesař on the correct interpretation of the Coriolis force[2]. The debate was complicated by many side issues, but the main problem was this: if the Foucault pendulum was oscillating, as it was often assumed[3], with its plane of swing fixed relative to the stars, why then was not the period the same, 23 hours and 56 minutes, everywhere on earth and not only at the poles? Instead it was 28 hours in Helsinki, 30 hours in Paris and 48 hours in Casablanca, i.e. the sidereal day divided by the sine of latitude. At the equator the period was infinite; there was no deflection. This could only mean that the plane of swing indeed was turning relative the stars. But how could then, as it was assumed, a "fictitious" inertial force be responsible for the turning?

One hundred years later, Einstein's five papers published in 1905 in *Annalen der Physik* are commonly used in undergraduate physics education whereas teachers and students, just like Denizot, Rudzki and Tesař, still struggle to come to terms with the Coriolis effect. This essay will sketch the complex and contradictory historical development of understanding the Coriolis Effect to about 1885. The continuing confusion since then is another story, but is undoubtedly related to our "Aristotelian" common sense. The reader's attention is directed to the copious endnotes for additional details.

http://www.meteohistory.org/2005historyofmeteorology2/01persson.pdf

Re: [HM] The Foucault pendulum.
Posted: Jan 27, 1999 12:59 AM

Plain Text Reply

John Dawson wrote:

>
> Although that is rather an old-fashioned science museum, it is one of the
> few places I've been that has a Foucault pendulum marked to show where the
> bob will be at a given hour -- the point being that it does *not* go
> through a full circle in 24 hours, as many suppose. (It would only do so at
> the poles.) I confess that I myself was unaware of the latitude dependence
> until I visited the CNAM. The precise equation involved is a simple example
> of a natural context in which the cosecant function arises.
>

Some years ago, a sequence of Foucault pendulums was built here at Monash by the late Carl Moppert of this department and (now Emeritus) Professor Bill Bonwick of Electrical Engeineering. The latest of this series still functions in the building which houses my office and it takes up the whole of an otherwise unused liftwell.

Bonwick devised a unique drive that can only accelerate the pendulum (and by just enough) in the direction of its motion, thius avoiding the problem of "running down".

A more serious problem with all Foucault pendulums is that of "ellipsing". For a pendulum to swing in a plane is an unstable mode of oscillation. The full solution is illustrated on the cover of the Dover edition of Routh's "Advanced dynamics of Rigid Bodies" and it consists of an elliptical motion with the ends of the ellipse rotating at a steady rate. This "ellipsing" must be suppressed as it is a much larger effect than the Foucault effect, which is hard to deteect if ellipsing is taking place.

Most Foucault pendulums use a device known as a Charron ring to this end, but the theory of this is not entirely agreed and the results not wonderfully good. In the American Journal of Physics of (some 10?) years ago there is a lengthy discussion on the matter.

Moppert & Bonwick did not use a Charron ring, but opted for a sponge

rubber sleeve at the maximum amplitude of the swing. Later this was replaced by further electrical controls.

The results are still in considerable error, but are the best ever achieved. Moppert conducted an extensive correspondence with the curators of all known Foucault pendulums at the time and many curators quite openly admitted to "cheating", by advancing or retarding the pendulum in the hours that the public had no access.

A smaller version of the Moppert-Bonwick pendulum hangs in the McCoy (Geology) Building at the University of Melbourne. Monash has another Foucault Pendulum on display in its Physics department, but this is a smaller and conventional affair with a Charron ring.

For more on the theory, see Moppert's article in Q J R Ast Soc 21 (1980), pp 108-118.

Mike Deakin

http://mathforum.org/kb/message.jspa?messageID=1176046

"The Hadley cell, named after ***George Hadley,*** *is a tropical atmospheric circulation which features rising motion near the equator, poleward flow 10–15 kilometers above the surface, descending motion in the subtropics, and equatorward flow near the surface. This circulation is intimately related to the trade winds, tropical rainbelts and hurricanes, subtropical deserts and the jet streams."*

"Hadley recognized that Earth's rotation plays a role in the direction taken by air mass that moves relative to the Earth, and he was the first to do so. Hadley's theory, published in 1735, remained unknown, but it was rediscovered independently several times. Among the re-discoverers was John Dalton, who later learned of Hadley's priority. Over time the mechanism proposed by Hadley became accepted, and over time his name was increasingly attached to it. By the end of the 19th century it was shown that Hadley's theory was deficient in several respects. One of the first who accounted for the dynamics correctly was William Ferrel. It took many decades for the correct theory to become accepted, and even today Hadley's theory can still be encountered occasionally, particularly in popular books and websites. [2] Hadley's theory was the generally accepted theory long enough to make his name become universally attached to the circulation pattern in the tropical atmosphere. In 1980 Isaac Held and Arthur Hou developed the Held-Hou Model to describe the Hadley circulation."

"The region of subsidence in the Hadley cell is known as the "horse latitudes".

https://en.wikipedia.org/wiki/Hadley_cell

"In 1686, Edmond Halley proposed his theory attempting to explain the Trade Winds. Halley's theory remained the most widely known internationally almost to the beginning of the 19th century.

Hadley was elected a fellow of the Royal Society on 20 February 1735, and on 22 May that year published a short paper in Philosophical Transactions (vol. 39, 1735, 58–62) giving his own explanation of the Trade Winds.[1] His theory, remained unknown, but it was independently created several times. Among the later creators was John Dalton, who later eventually became aware of Hadley's priority. During the second half of the 19th century the theory gradually became known as "Hadley's principle".[2]

In retrospect the crucial step forward was the recognition that the Earth's rotation plays a role in the direction taken by air mass that moves relative to the Earth. That element had been missing in Hadley's proposal.[citation needed]

Later, in the second half of the 19th century, Hadley's theory was shown to be deficient in several respects. Hadley's theory is based on an assumption that when air mass travels from one latitude to another its linear momentum is conserved. However, since the air mass is at all times in a state of circumnavigating the Earth axis, it is in fact the angular momentum that is conserved, an effect known as the Coriolis effect. When using the correct angular momentum conservation in calculations the predicted effect is twice as large as when the erroneous conservation of linear momentum is used. The fact that Hadley's principle is a deficient theory is not known to all people who should know; it can still be found in popular books and popular websites."

https://en.wikipedia.org/wiki/George_Hadley

explained the tendency of the wind to approach the equator from the north-east and south-east as a consequence of the sun's varying path between the equinoxes[8].

The renowned astronomer Edmond Halley (1656-1742) now entered the debate and suggested as the main mechanism the diurnal displacement from east to west of the sun's heating in the tropical belt. The deviation of the trade winds from straight east was due to the meridional flow of dense air toward the latitude of maximal radiative heating[9]. In subsequent discussions Robert Hooke (1635-1703) invoked the centrifugal force of the earth's rotation to explain the equatorward component of the trade winds. By this the debate ended, Halley and Hooke became occupied with other matters and no new ideas came forward for almost half a century.

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The "Hadley Principle" is born

The novelty of George Hadley's explanation was to take into consideration the diurnal motion of the earth around its axis, rather than the sun's apparent motion due to the earth's rotation:

> For let us suppose the Air in every Part to keep an equal Pace with the Earth in its diurnal Motion; in which case there will be no relative Motion of the Surface of the Earth and Air, and consequently no Wind; then by the Action of the Sun on the parts about the Equator, and the Rarefaction of the Air proceeding there from, let the Air be drawn thither from the N. and S. parts.

http://www.meteohistory.org/2006historyofmeteorology3/2persson_hadley.pdf

Thiesen's article started a debate with Sprung which soon came to involve other meteorologists and physicists like Fr. Roth in Buxtehude, H. Bruns in Leipzig, K. Weirauch in Dorpart (Tartu in today's Estonia) and Julius Hann. Hann was at this time working on his *Handbuch der Klimatologie* and Sprung, upon the request of von Neumayer, on a groundbreaking textbook on dynamic meteorology. The debate made to a large extent reference to the motions of the atmosphere and oceans, both to illustrate certain properties of the Coriolis effect, but also to explain the atmospheric motions. Since this was done without always distinguishing between forced and inertial motion, the discussion could become quite confused.

Among the "paradoxes" that served to complicate the debate (excluding "mysteries" with the Foucault pendulum):

1. The "Coriolis force" does not depend on the radius of the earth, which therefore can be treated as a perfect sphere. But on a rotating spherical planet every object would be accelerated towards the equator - so there would be no "Coriolis effect."
2. Common sense tells us that it is through friction that a body "knows" it is moving over a rotating surface. But how much friction is "needed"? The Coriolis force is after all an inertial force and friction would complicate the mathematics…
3. Hadley's model implied 40 m/s Trade winds. But we know that his principle of conservation of absolute velocity was wrong, whereas the principle of conservation of absolute angular momentum is correct. But this principle yields 80 m/s Trade winds!

The German debate is interesting and thought provoking, but we have to stop here. The development up to 1885 can be treated as historical since the problems have been resolved. However, those discussed since *are still unsolved or at least controversial*. By 1885 almost

The German debate is interesting and thought provoking, but we have to stop here. The development up to 1885 can be treated as historical since the problems have been resolved. However, those discussed since *are still unsolved or at least controversial*. By 1885 almost everything about the Coriolis effect was known and widely published. The following 120 years, i.e. up to now, have seen a constant repetition of the discussions and debates of the preceding 120 years, with interesting additions provided by new technological proposals such as a rotating space station.[34]. In general we meet the same attempt then as now to reconcile mathematics with Hadley's, Bertrand's and others' flawed but intuitively appealing "common sense" explanations and conceptual models. One can wonder why?

http://www.meteohistory.org/2005historyofmeteorology2/01persson.pdf

*"In physics, the **Coriolis force** is an inertial force (also called a fictitious force) that acts on objects that are in motion relative to a rotating reference frame. In a reference frame with clockwise rotation, the force acts to the left of the motion of the object. In one with anticlockwise rotation, the force acts to the right. Though recognized previously by others, the mathematical expression for the Coriolis force appeared in an 1835 paper by French scientist Gaspard-Gustave de Coriolis, in connection with the theory of water wheels. Early in the 20th century, the term Coriolis force began to be used in connection with meteorology. Deflection of an object due to the Coriolis force is called the 'Coriolis effect'.*

Newton's laws of motion describe the motion of an object in an inertial (non-accelerating) frame of reference. When Newton's laws are transformed to a rotating frame of reference, the Coriolis force and centrifugal forceappear. Both forces are proportional to the mass of the object. The Coriolis force is proportional to the rotation rate and the centrifugal force is proportional to its square. The Coriolis force acts in a direction perpendicular to the rotation axis and to the velocity of the body in the rotating frame and is proportional to the object's speed in the rotating frame. The centrifugal force acts outwards in the radial direction and is proportional to the distance of the body from

the axis of the rotating frame. These additional forces are termed inertial forces, fictitious forces or pseudo forces.[1] They allow the application of Newton's laws to a rotating system. They are correction factors that do not exist in a non-accelerating or inertial reference frame.

A commonly encountered rotating reference frame is the Earth. The Coriolis effect is caused by the rotation of the Earth and the inertia of the mass experiencing the effect. Because the Earth completes only one rotation per day, the Coriolis force is quite small, and its effects generally become noticeable only for motions occurring over large distances and long periods of time, such as large-scale movement of air in the atmosphere or water in the ocean. Such motions are constrained by the surface of the Earth, so only the horizontal component of the Coriolis force is generally important. This force causes moving objects on the surface of the Earth to be deflected to the right (with respect to the direction of travel) in the Northern Hemisphere and to the left in the Southern Hemisphere. The horizontal deflection effect is greater near the poles and smallest at the equator, since the rate of change in the diameter of the circles of latitude when travelling north or south, increases the closer the object is to the poles.[2] Rather than flowing directly from areas of high pressure to low pressure, as they would in a non-rotating system, winds and currents tend to flow to the right of this direction north of the equator and to the left of this direction south of it. This effect is responsible for the rotation of large cyclones (see Coriolis effects in meteorology). To explain this intuitively, consider how an object that moves northwards from the equator has a tendency to maintain its greater speed at the equator (rotating around towards the right as you look at the sphere of the Earth), where the "horizontal diameter" is larger, and therefore tends to move towards the right as it passed northwards where the "horizontal diameter" of the Earth (the rings of latitude) is smaller, and the linear speed of local objects on the Earth's surface at that latitude is slower."

https://en.wikipedia.org/wiki/Coriolis_force

"Italian scientists Giovanni Battista Riccioli and his assistant Francesco Maria Grimaldi described the effect in connection with artillery in the 1651 Almagestum Novum, writing that rotation of the Earth should cause a cannonball fired to the north to deflect to the east.[3] The effect was described in the tidal equations of Pierre-Simon Laplace in 1778.

Gaspard-Gustave Coriolis published a paper in 1835 on the energy yield of machines with rotating parts, such as waterwheels.[4] That paper considered the supplementary forces that are detected in a rotating frame of reference. Coriolis divided these supplementary forces into two categories. The second category contained a force that arises from the cross product of the angular velocity of a coordinate system and the projection of a particle's velocity into a plane perpendicular to the system's axis of rotation. Coriolis referred to this force as the "compound centrifugal force" due to its analogies with the centrifugal force already considered in category one.[5][6] The effect was known in the early 20th century as the "acceleration of Coriolis",[7] and by 1920 as "Coriolis force".[8]

In 1856, William Ferrel proposed the existence of a circulation cell in the mid-latitudes with air being deflected by the Coriolis force to create the prevailing westerly winds.[9]

Understanding the kinematics of how exactly the rotation of the Earth affects airflow was partial at first.[10] Late in the 19th century, the full extent of the large scale interaction of pressure gradient force and deflecting force that in the end causes air masses to move 'along' isobars was understood."

https://en.wikipedia.org/wiki/Fictitious_force

"A ***fictitious force****, also called a* ***pseudo force****,[1]* ***d'Alembert force****[2][3] or* ***inertial force****,[4][5] is an apparent force that acts on all masses whose motion is described using a non-inertial frame of reference, such as a rotating reference frame."*

This was an incredible finding, since it is not obvious why the sine function is the correct one to use in an expression to describe the time it should take the plane of the pendulum to complete a circle; and proofs of the sine law are not trivial.[35] Foucault had obtained this surprising result without mathematical training or experience in deriving mathematical equations, and he did it before the mathematicians had even begun to understand the problem.

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problem.

But the mathematicians refused to be impressed by Foucault's formula. A week after Foucault's demonstration at the Observatory and the presentation of his paper describing the pendulum experiment and the sine law, members of the Academy scrambled to explain his experiment their way, as well as to protect themselves from criticism. They had all been put to shame by Foucault's achievement. Was it really possible that Foucault should discover something that the mathematicians' own equations did not predict? And how in the world would someone with no training in mathematics develop a law describing how fast the pendulum's plane must rotate for a pendulum placed *anywhere* on the planet? Foucault only had one observation point: Paris. This was a stunning achievement for Foucault, they knew, and an equally embarrassing situation for them, the "experts."

The mathematicians were quick to try to respond to the shock of Foucault's incredibly simple demonstration of the rotation of the Earth. They made the problem very complicated by referring to their old equations, searching to find in them something that "should have told them" what Foucault's pendulum,

majestically swinging and turning as the Earth rotated, was showing them so clearly and so simply.

The first to make a written presentation read in front of the Academy at its February 10 meeting was Jacques Binet (1786–1856). Binet started by saying: "Foucault has asked me in what way the mechanical result he had obtained accords with mathematical theories." He proceeded to quote a succession of results by mathematicians over generations:

> In Chapter 5 of Volume 4 of his *Celestial Mechanics,* Laplace deals with falling bodies, but not pendulums. Poisson dealt with this subject in 1837 in his article in the *Journal de l'École Polytechnique* (vol. 26). There he said: "This force acting on the plane of oscillation of the pendulum is too small to move the pendulum perceptibly, to have an ap-

preciable influence on its movement." This fact is contrary to the experiments of Foucault.

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Binet then continued to try to defend this embarrassing failing of his revered late colleague (Poisson had died eleven years earlier). It seemed he would stop at nothing, for this is what he said: "But the passage I just cited permits a doubt: Poisson doesn't report a calculation of the force of which he speaks, and thus it is insufficient to allow us to know whether the perturbing force is *very small* [his italics], to conclude that it will only produce an imperceptible effect after a large number of oscillations."[36] He then addressed the sine law—that stunning piece of mathematical deduction by the untrained Foucault. To try to

Pendulum: Leon Foucault and the Triumph of Science By Amir D. Aczel

The Rotation of the Earth.

"IT must have struck all those who have been working in science, ever and anon, that when they fancied they had found something new, they find it was done by Sir Charles Wheatstone years ago."

This remark was made by William Spottiswoode at the Science Conferences at South Kensington in 1876, after a lecture by Professor W. G. Adams on Wheatstone's Acoustical discoveries.

Foucault's description of his famous pendulum experiment for demonstrating the rotation of the earth appeared in the "Comptes Rendus," February, 1851, vol. xxxii., pp. 135-138.

Wheatstone's "Note relating to M. Foucault's new mechanical proof of the rotation of the earth," in the Proceedings of the Royal Society, May 15, 1851, pp. 65-68, contained a description of an apparatus to exhibit the effects of the earth's rotation.

As no reference to this apparatus is made either by M. Blum ("Comptes Rendus," February 18, 1907, pp. 364-366) or in the description of his apparatus at p. 226 of the October issue of "KNOWLEDGE," perhaps the following may be of interest.

Wheatstone's apparatus (Fig. 1) consists of a graduated semi-circular arch, APB, of one or two feet radius (corresponding to a semi-meridian of the earth) which can be turned on a vertical axis. Central pull (corresponding to the force of gravity) is obtained by employing a spiral spring, CP, made of thin hardened brass wire coiled to a diameter of ¼ inch. By means of a sliding clamp, P, this spring can be set at any angle.

purely experimental method of investigating the behaviour of a Foucault pendulum at various latitudes.

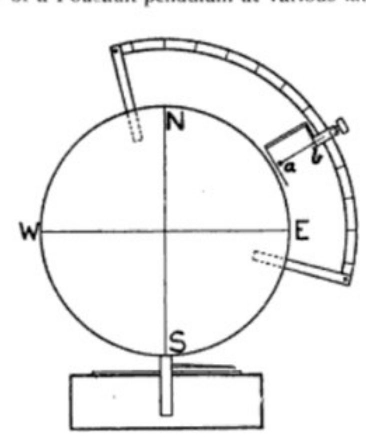

FIG. 2.

The apparatus consists of a globe, NESW (about 18 inches diameter), capable of rotation on its axis, NS, and a pendulum, *ab*, consisting of a piece of thin steel wire (about six inches long) of uniform circular section, with a small leaden bob. The upper end of the wire is soldered into a brass head, which can be securely clamped at any latitude, so that the pendulum when at rest at any latitude points to the centre of the globe. Divided circles are provided for observing the angles of

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of a sliding clamp, P, this spring can be set at any angle.

When the spring was vertical and was started by hand vibrating in any plane it kept on vibrating in that plane, however much the arch was turned on its

rest at any latitude points to the centre of the globe. Divided circles are provided for observing the angles of rotation of the globe, and of the plane of the pendulum.

When the pendulum, at any latitude, θ, is set vibrating by hand in any particular plane and the globe then rotated through an angle α, the angle of rotation, β, of the plane of the pendulum can be observed with an accuracy sufficient to prove very effectively that

$$\beta = \alpha \sin \theta.$$

The methods of fixing the pendulum and its graduated circle were found, owing to want of rigidity,

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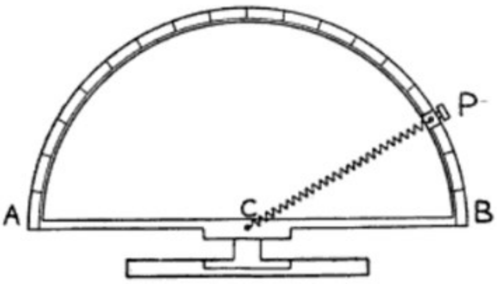

Fig. 1.

axis. When the angle, PCB, was 30° it was found that two revolutions of the arch were required for every revolution of the plane of vibration of the spring relatively to the arch.

In other positions of CP it was found that the number of revolutions of the arch required for every revolution of the plane of the spring relatively to the arch was equal to the reciprocal of the sine of the angle PCB. The original apparatus is, I believe, still preserved in the Museum of King's College, London.

In endeavouring to adapt Wheatstone's apparatus so as to conform more nearly in its outward configuration with the conditions of the real Foucault-pendulum experiment, the writer devised the following apparatus (Fig. 2) in August, 1905. It was described in the "Practical Teacher" of May, 1906, in an article written with the object of suggesting to science teachers a

rotation of the globe, and of the plane of the pendulum.

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The methods of fixing the pendulum and its graduated circle were found, owing to want of rigidity,
to damp to some extent the vibrations of the pendulum itself, and a wooden gibbet was shortly afterwards employed, the base of which could be secured at any latitude on the globe. The length of the pendulum was also increased so as to lengthen the time the pendulum would keep on vibrating.

With a pendulum 1 mm. diameter and 12 inches long, when the bob is started vibrating with a path three inches long, after 30 seconds have elapsed the path is still half an inch long, so that ample time is provided for taking observations of angles.

It will be seen that M. Blum's apparatus resembles the above very closely, though it is, perhaps, a little more complicated. DAVID BAXANDALL.

Popular Lecture on the Moon.—Messrs. Newton are offering to amateur lecturers a series of sixty lantern slides of the moon, the photographs being designed to show successively the movements and phases of the moon, alike in relation to the sun and to the earth; and also, on a very complete scale, the natural features of the moon. Some forty photographs of the craters of the moon are embraced in the series, and the only alteration to the series that we can suggest is that the photograph of a terrestrial volcano, like Vesuvius, which is inserted for comparison with the lunar craters, should be replaced by some slides of the Hawaiian craters. Volcanoes like Vesuvius are comparatively rare on the moon.

Knowledge and Illustrated Scientific News, Volume 31

Note relating to M. Foucault's new mechanical proof of the Rotation of the Earth. (1851)

by Charles Wheatstone

The following papers were read: - 1. "Note relating to M. Foucault's new mechanical proof of the Rotation of the Earth." By C.Wheatstone,

Esq., Corresponding member of the Acadamies of science of Paris, Berlin, Brussels, Turin, Rome, Dublin, &c. Reveived May 15, 1851.

The experiment which led M. Foucault to his ingenious and interesting researches relating to the motion of the earth, is stated by him thus:- "Having fixed on the arbor of a lathe and in the direction of the axis, a round and flexible steel rod, it was put in vibration by deflecting it from its position of equilibrium and leaving it to itself. A plane of oscillation is thus determined, which, from the persistence of the visual impressions, is clearly delineated in space; now it was remarked that, on turning by the hand the arbor which serves as a support to this vibrating rod, the plane of oscillation is not carried with it."

This persistence of the plane of oscillation of a vibrating rod, notwithstanding the rotation of the point to which its end is fixed does not appear to have hitherto been made the subject of philosophical observation. Ordinary notions even seem to have been opposed to this now recognized fact. Chladni in his treatise on Acoustics, in the chapter, "On the co-existence of vibrations with other kinds of motion." states as follows:-

"Vibratory motion may co-exist with all other kinds of motions in an infinity of different manners, as has been demonstrated by Dan. Bernouilli, and L. Euler in vols. xv and xix, of the Nor. Comment. Acad. Petrop., and confirmed by experiment. These co-existences of different motions occur in all sonorous bodies without exception; we may, for example, produce the sound of a string stretched on a board, or that of a plate, a tuning fork, a bell, &c; and while the vibrations still last, impress on this sonorous body a motion of rotation round its axis, and at the same time a progressive motion: thus all these motion may be performed in the same time, without one being hindered by the other; but the absolute motion of each point will be very complicated."

Now this is true only when the vibrating body is constrained to vibrate in one direction. When the rod or string is equally flexible in every direction, the plane of vibration given to it from any original impulse is constantly maintained whatever may be the velocity of rotation communicated to its point of support, provided the axis of vibration remains in the same position, or move only parallel to itself.

This observed independence of the plane of oscillation on the point of attachment led M. Foucault to assume, that were a flexible pendulum suspended from a fixed point in the prolongation of the axis of the Earth, that is above the plane of oscillation maintaining an invariable position in space would appear to a spectator on the earth's surface and moving with it to make an entire revolution in twentyfour hours, but in the opposite direction to that of the rotation of the Earth.

What takes place at other points of the earth's surface is more difficult to determine; but M. Foucault, from mechanical and geometrical considerations, was led to the conclusion that the angular displacement of the plane of oscillation is equal but opposite to the angular momentum of the earth multiplied by the sine of the latitude. According to the theory of rotation, first established by Frisi and more fully developed by Euler and Poinsot, the velocity of rotation of the earth may be considered as the resultant of two angular velocities, one round the vertical of the point where the observer is placed, and the other round the meridian or horizontal line lying N. and S. The component of the angular velocity estimated round the vertical axis is n sin gamma, and the plane of oscillation not participating in this motion remains at rest with respect to it, and therefore appears to an observer moving with the point, to rotate with the same velocity in the contrary direction.

The experiment made by M. Foucault is said, both in the direction and magnitude of the motion of the plane of oscillation of the pendulum, fully to conform the indications of the theory. The difficulty, however, of the mathematical investigation of the subject, and the delicacy of the experiment, liable as it is to so many extraneous causes of error, have induced many persons to doubt either the reality of the phenomenon or the satisfactoriness of the explanation. Another experimental proof, therefore, not depending on the rotation of the earth, that the plane of oscillation of a vibrating line remains at rest with relation to the vertical component of the real axis of rotation, may not be unacceptable. With this in view I have devised the apparatus I am about to describe.

A semicircular arch from one one to two feet radius is fixed vertically on a horizontal wheel, and may thus be moved with any degree of rapidity from any one azimuth to another. A rider slides along the inner edge of the arch, which is graduated, and may be fixed at any degree marked thereon. A spiral spring wire, by means of which a slow vibration is obtained with a comparatively short length, is attached at the lower end to a pin fixed in the axis of the semicircle, so that the point of attachment may be the axis of rotation, and at the upper end it is fixed to a similar pin in a parallel position fixed to the rider. The vertical semicircle is not placed in a diameter of the horizontal wheel, but parallel to it, at such distance as not to intercept, from the eye of the observer, the vertical plane passing through the diameter, and in which plane the wire in all its positions remains.

When the upper end of the wire is placed at 90°, that is when it coincides with the axis of rotation, if the wire be caused to vibrate in any given plane, say from N. to S., it will continue to do so whatever rotation may be communicated to the wheel; so that with respect to the moving wheel, or the axis of the wire, the plane of vibration will move with the same velocity and in the opposite direction. When the rider is fixed at 30°, and the wire makes therefore an angle of 60° with the axis of rotation so as to describe in its motion the surface of a cone having this inclination to the vertical, it will be observed that the plane of the vibration makes one complete rotation during two rotations of the wheel; this is best observed by fixing the eye so that its axis shall coincide with a line in the same vertical plane with the wire, while walking round with the wheel during its rotation. When the rider is fixed at 19½°, the plane of vibrations makes one rotation during three rotations of the wheel; when fixed at 14½°, it makes one rotation during four of the wheel, &c.; and when it is fixed at 0°, the wire lying horizontally, no rotation of the plane of vibration occurs. It is needless to observe that the sines of 90°, 30°, 19½°, 14½°, 0°, correspond to the numbers 1, 1/2, 1/3, 1/4, 0, the reciprocals of the numbers expressing the respective times of rotation. [1]

It is not necessary that the wire should have one of its ends fixed in the axis of rotation: if it be parallel to a wire so fixed, the rotation of the plane of vibration will be exacly similar; in such a case the wire or axis of vibration will describe the surface of two cones having their common apex in the axis of rotation.

The axis of a flexible pendulum can only assume a position vertical to the point of the earth's surface over which it is placed. Were it possible to maintain the vibration of a stretched wire occasioned by an original impulse, for a sufficient length of time, the apparent rotation

of its plane of vibration would vary with the inclinations of the wire to the axis of the earth: placed in this axis, it would make a rotation in 24 hours, it would become progressively slower according to the law above given, as it approaches the plane of the equator, and when anywhere in this plane the vibrations would always be performed in the same direction.

1. When the dimensions of the apparatus are as above given, I find that hardened brass wire (no 26), coiled so as to form a helix of one quarter of an inch in diameter, shows the effect well. The thickest spiral wire employed in the manufacture of artificial flowers, which can be procured of any wire-drawer, will also answer the purpose.
   The best way of setting the wire in vibration is to press the finger upon it in the middle, so as to deflect it in the plane in which the vibrations are required to continue, and then suddenly to withdraw the finger in the direction of the vibrations. The deflection must not be too great, or the elasticity of the wire will be injured.

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